TESTS

OF

HOUSE HEATING BOILERS

BY

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THESIS

. FOR .

DEGREE OF BACHELOR OF SCIENCE

IN .

THE SCHOOL OF MECHANICAL ENGINEERING,

COLLEGE OF ENGINEERING.

UNIVERSITY OF ILLINOS.

1897.

House Tests.

The following is the result of a weeks test of the heating apparatus in the houses of Professor Breckenridge at No. 1005, Professor Burrill at No. 1007, and Mr. Page at No. 1008, East Green Street, Urbana, Illinois.

The test originated in the desire of the owners of the three houses of obtaining some knowledge of the comparative cost of heating their homes with the style of heater they had. in their homes.

Professor Breckenridge used a "Cottage" Hot Water Heater, firing hard coal, and Professor Burrill had a "Robinson & Burr" Steam Heater. while Mr. Page heated with a Steam apparatus of his own design using as Professor Burrill did also soft coal to run it. This difference in heaters together with the difference in size and construction of the houses made a comparative test somewhat difficult.

The week commenced Thursday Afternoon, February 25 and ended on the Thursday Afternoon of the week following. The heaters were used in the same manner as they would have been any other

seven days of a like range of temperatures. The usual fireman fired in each case; the experimenter going around morning and evening of each day to weigh coal and ashes.

In making the start, the ashes were cleaned out of the fire and the quantity of live and green coal on the grate noted. A quantity of fresh coal was weighed in a large hod hung on an accurate spring balance, and then placed on a pile in a place convenient for firing. Each house was provided with a number of tin case thermometers which were distributed over the place so as to obtain the average temperature of the building as nearly as possible.

Each owner was instructed to read temperatures throughout the house as often as he found it convenient; to fire coal from the weighed pile only, recording the time of such firing, and to save all ashes so that they might be weighed.

Morning and evening the coal remaining on the pile was reweighed and by subtraction the amount fired in the internal was known. The ashes were also weighed and the weight recorded.

The test was closed at the end of the seven days by allowing the fire to assume the condition of a week previous as nearly as possible.

In working for results, the average temperature of different parts of the houses was found by platting the observed temperatures, connecting these points with straight lines, planimetering the area under the curves and dividing by the projected length of the curve. This method gave more accurate results, perhaps, than the simple averaging of readings since the intervals of time between were not constant.

Theexternal temperatures were obtained from the bulletin issued by the United States Experimental Station located at the University.

Results of Test.

Ref. No.	Article considered.	Professor Purrill's House.	Mr Page's House.	Professor Freckon-ridge's House.
1.	Cubic contents, cubic feet	21922	13207	24928
2.	Coal burned, pounds	1635	1894	1397
3.	Ashes, pounds	184	188	171
4.	Coal burned per 1000 cubic feet contents, pounds	74.57	128.58	56.04
5.	Cost of coal per ton, dollars	1.85	2.00	5.20
6.	Cost of heating 1000 cubic feet one week, cents	8.18	12.82	14.58
7.	Average temperature of house, degrees	84.8	85.4	84.5
8.	Number of degrees above external temperature,	38.3	38.9	38.0
9.	Cost of coal to maintain this temperature, dollars	1.35	1.89	3.83
10.	Cost to raise temperature of house one degree, cents	3.52	4.34	9.55
11.	Cost to raise temperature of 1000 cubic feet one degree, cents	.160	.329	.377
12.	Average temperature of water or steam in heater, degrees,	214	218	152
13.	Total number of "radiator hours", = hours x radiating surface	58480	43480	82318

External Temperatures.

Date.	Maximum Temperature	Minimum Temperature	Mean Temperature	Rain Inches	Humidity	Barometer 7 A.M.	Temperature 2 P.M.
25	33	18	23		88	30.158	28
26	23	17	11		94	30.248	13
27	25	2	17		89	30.577	23
28	37	22	31		85	30.398	38
1	43	30	38		91	30.171	39
2	43	32	38	1.5	100	29.933	38
3	37	24	24		88	30.032	26
4	35	20	32	1.1	97	30.239	33
Aver	34.2	19.8	28.5	2.6	80.2	30.584	29.5

Professor Burrill's House.

The home of Professor Burrill is a compact, square shaped house of plain frame construction, set on a brick basement. It is rather warmly built fronting the north and surrounded on all sides by good size trees.

The heater used is one manufactured by Robinson and Burr of Champaign. It is a vertical fire tube boiler, fired internally.

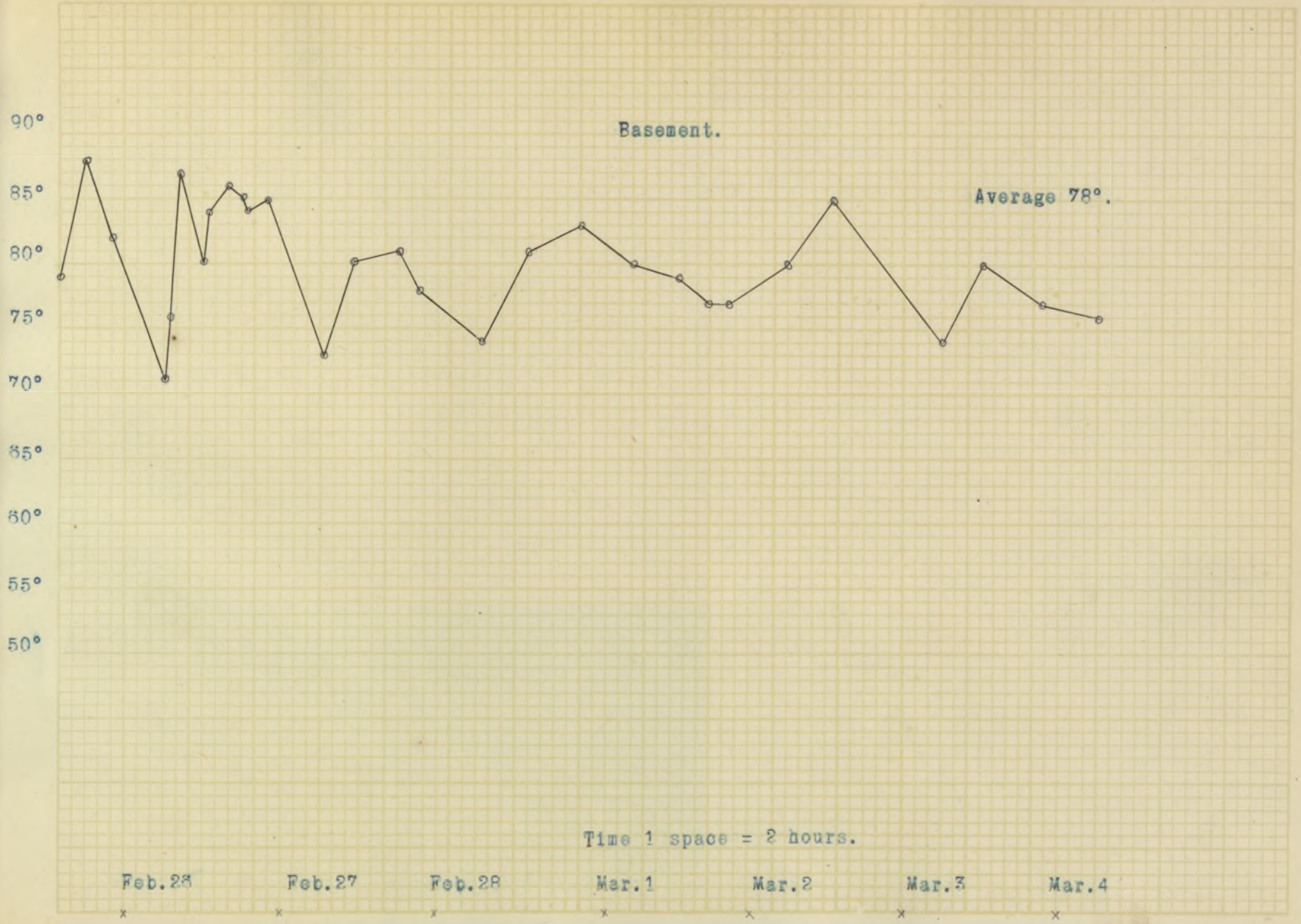
The gases after passing through the tubes are deflected by a cast iron pan down around the shell of the boiler before being allowed to pass to the chimney. Cuts of boiler are shown.

This heater although burning very cheap coal was fired in an excellent manner; the coal being well spread and the dampers carefully regulated.

The house seemed to have an abundant supply of radiating surface. The actual surface being 450□' while the formulae of Carpenter called for only 438□' and Wills only 394□'.

Professor Burrill's House.

Down Stairs.	Sq. Ft. of Glass in each Apartment				Total No. Sq. Ft. of Glass.	Linear Ft. Exposed Wall and Glass Facing.				Total No. Linear Ft. Exposed Wall	Sq. Ft. Wall	Sq. Ft. Exposed Glass	Cu. Ft. Air Space in each Apartment.	Cubic Contents.	Sq. Ft. Radiating Surface (Carpenter)	Sq. Ft. Radiating Surface (Willis)	Amount Used.
	N	E	W	S		N	E	W	S								
No.1. West Parlor	28		28		52	14		18		32	320	288	243	2430	55	54	80
No.2. Hall	5				5	7				7	70	65	128	1280	17	12	80
No.3. East Parlor	28	28			52	14	18			32	320	288	243	2430	55	54	80
No.4. Study	13		13	3	29	4		18	11	31	310	281	142	1420	40	37	30
No.5. Dining Room		11	11	31	53		3	3	11	17	178	123	190	1980	45	45	30
No.6. Kitchen				13	13				12	12	124	111	198	2048	30	23	20
No.7. Pantry																	
No.8. Backstairs																	
Up Stairs.																	
No.9. Dining Room C		12		12	24			18	9	25	250	228	150	1500	35	32	30
No.10. Kitchen Cham.				12	12				12	12	108	98	104	903	18	18	20
No.11. W. Parlor C.	12		12		24	12		18		30	300	278	243	2430	47	39	40
No.12. E. Parlor C.	12	12			24	13	18	18		31	310	288	250	2500	48	40	80
No.13. Hall Chamber	13				13	9	4	4		17	170	157	130	1300	25	22	30
No.14. Bath Room					4								38	380	4	4	10
No.15. Hall				12	12				6	6	60	48	138	1380	19	18	
No.16. Back Stairs																	

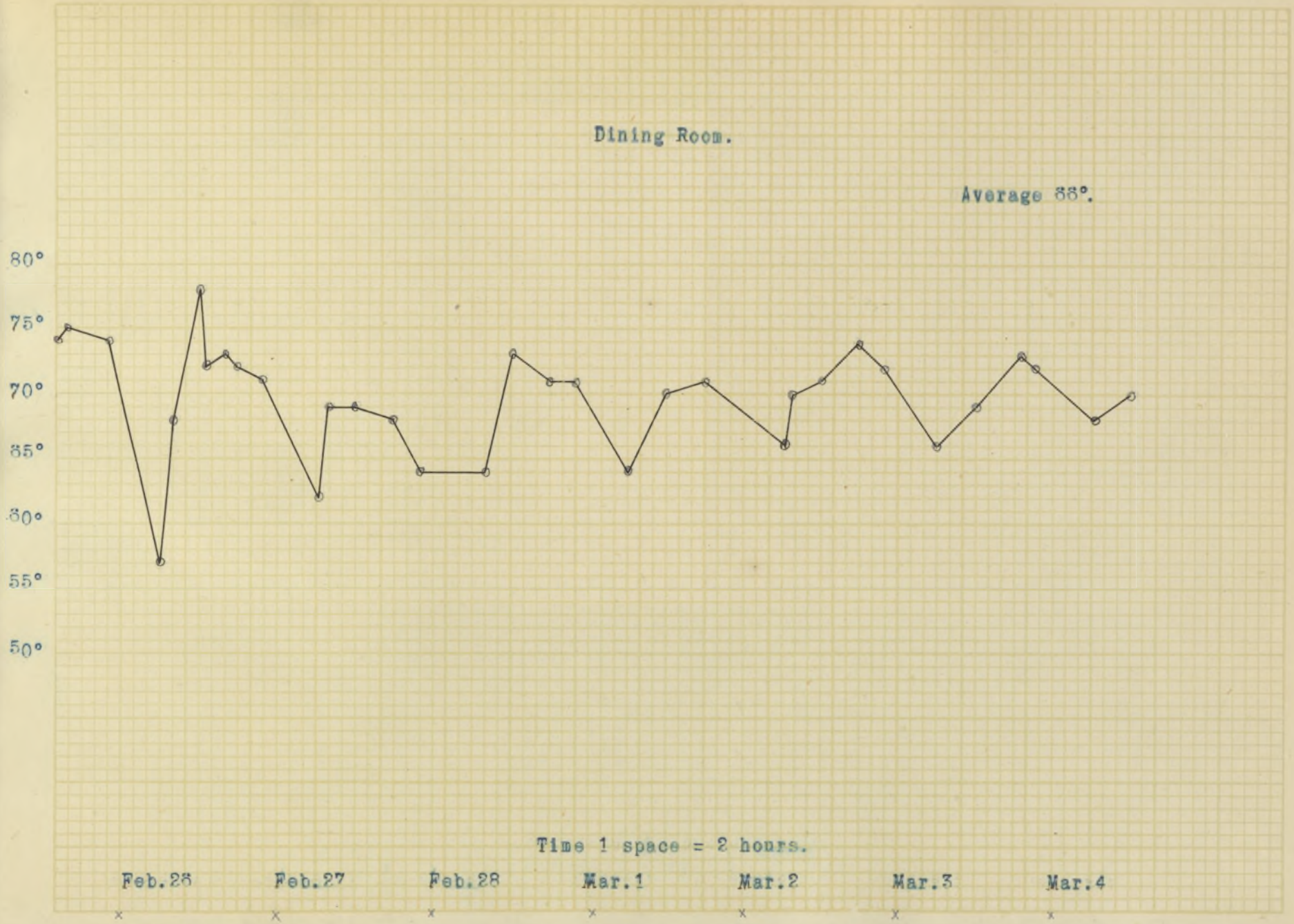

Basement.
Average 78°.
90°
85°
80°
75°
70°
65°
60°
55°
50°
Time 1 space = 2 hours.
Feb.26
Feb.27
Feb.28
Mar.1
Mar.2
Mar.3
Mar.4

Parlor.

Average 87°.

Time 1 space = 2 hours.

Feb. 26 | Feb. 27 | Feb. 28 | Mar. 1 | Mar. 2 | Mar. 3 | Mar. 4


Dining Room.
Average 68°.
80°
75°
70°
65°
60°
55°
50°
Time 1 space = 2 hours.
Feb.26
Feb.27
Feb.28
Mar.1
Mar.2
Mar.3
Mar.4

Study.

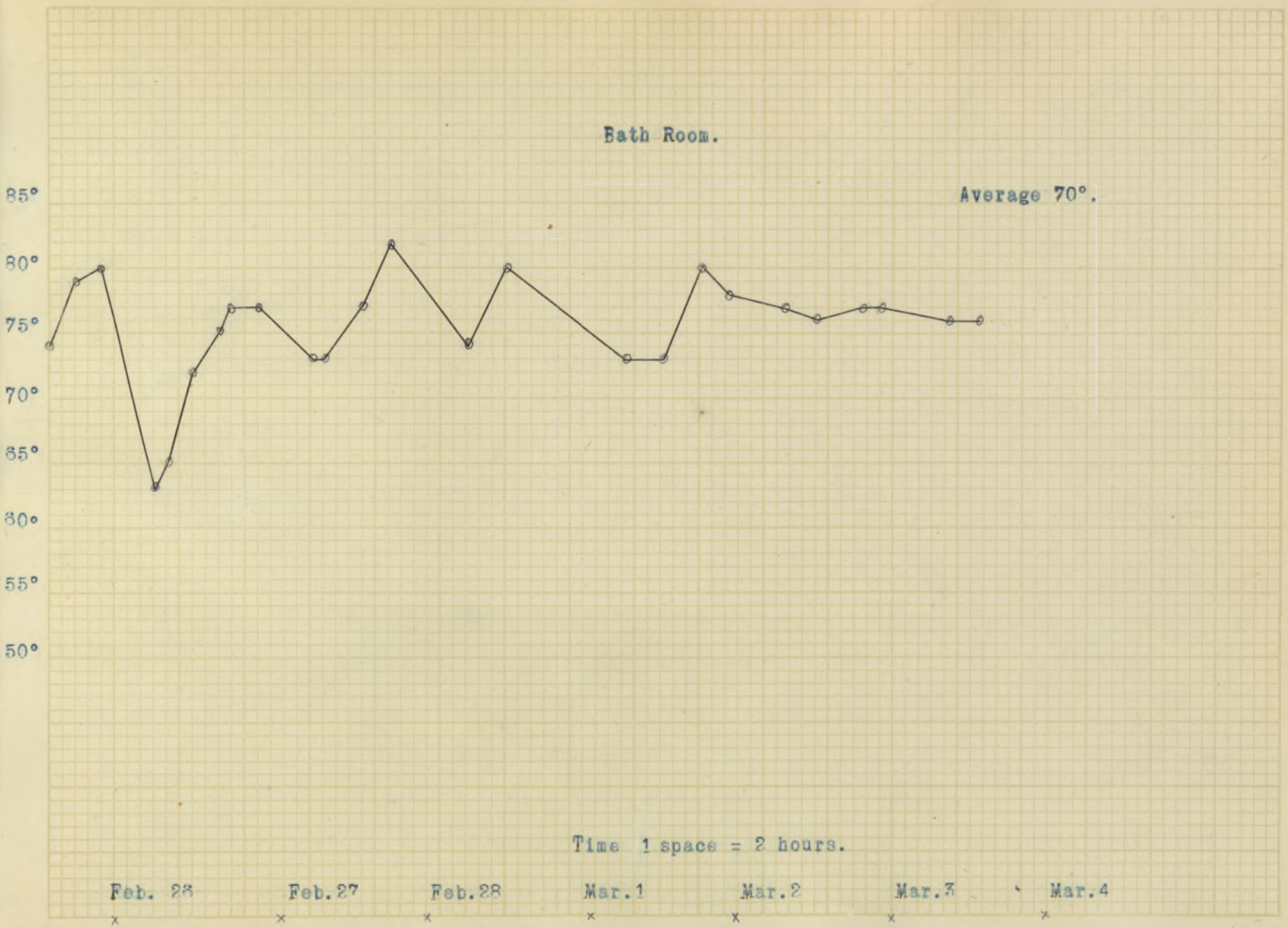
Average 65°.

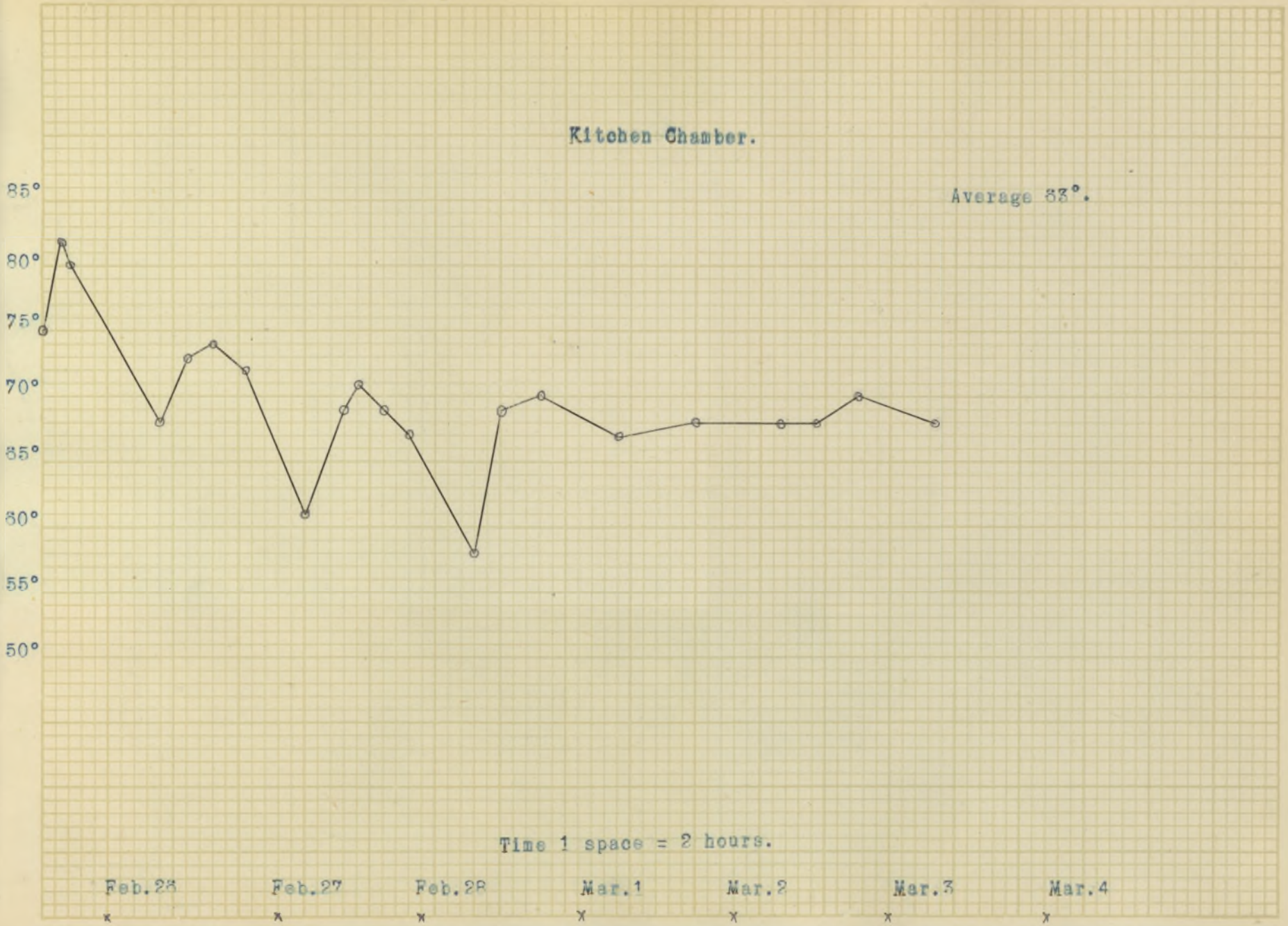
Time 1 space = 2 hours.

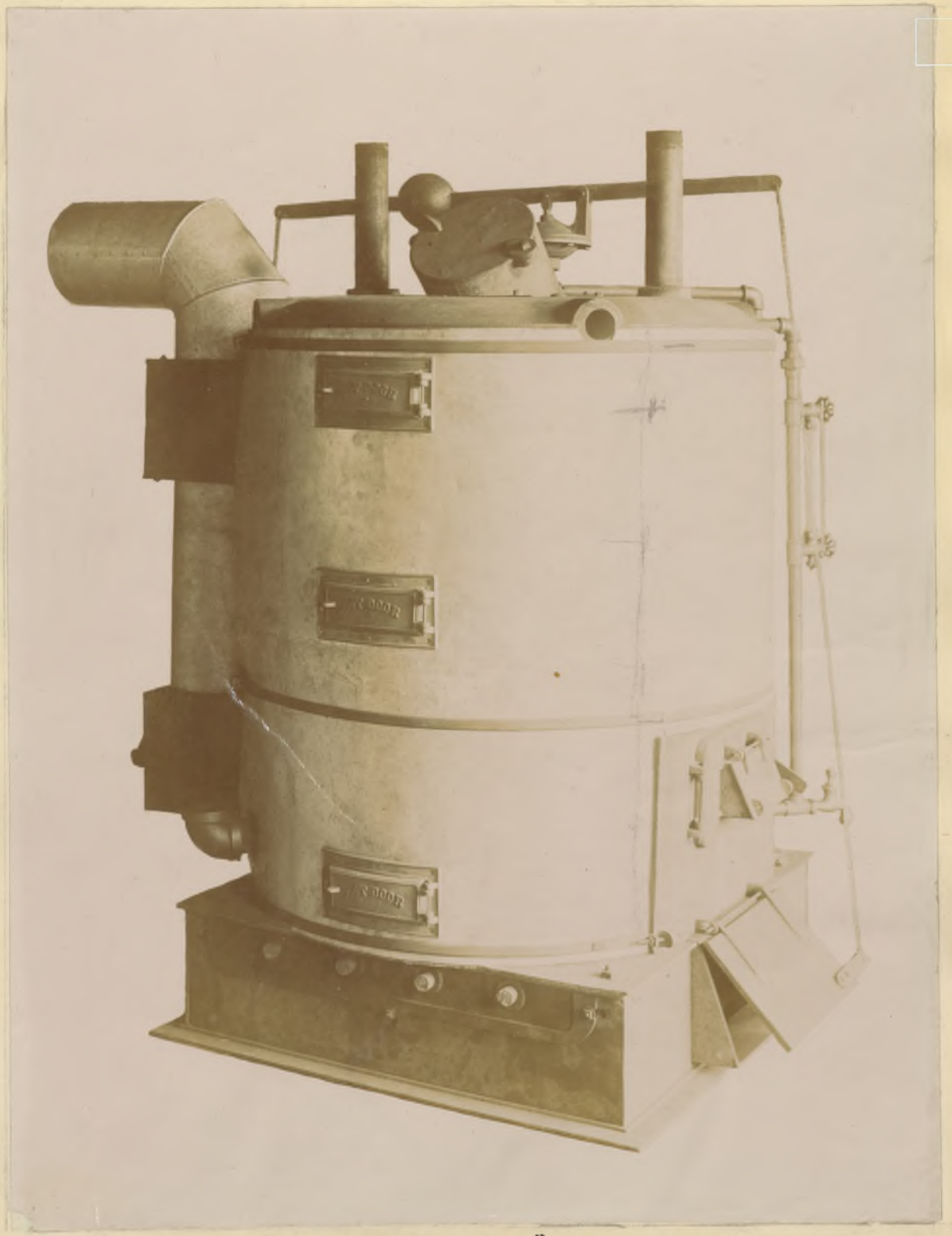
Feb. 26 | Feb. 27 | Feb. 28 | Mar. 1 | Mar. 2 | Mar. 3 | Mar. 4

Hall Chamber.

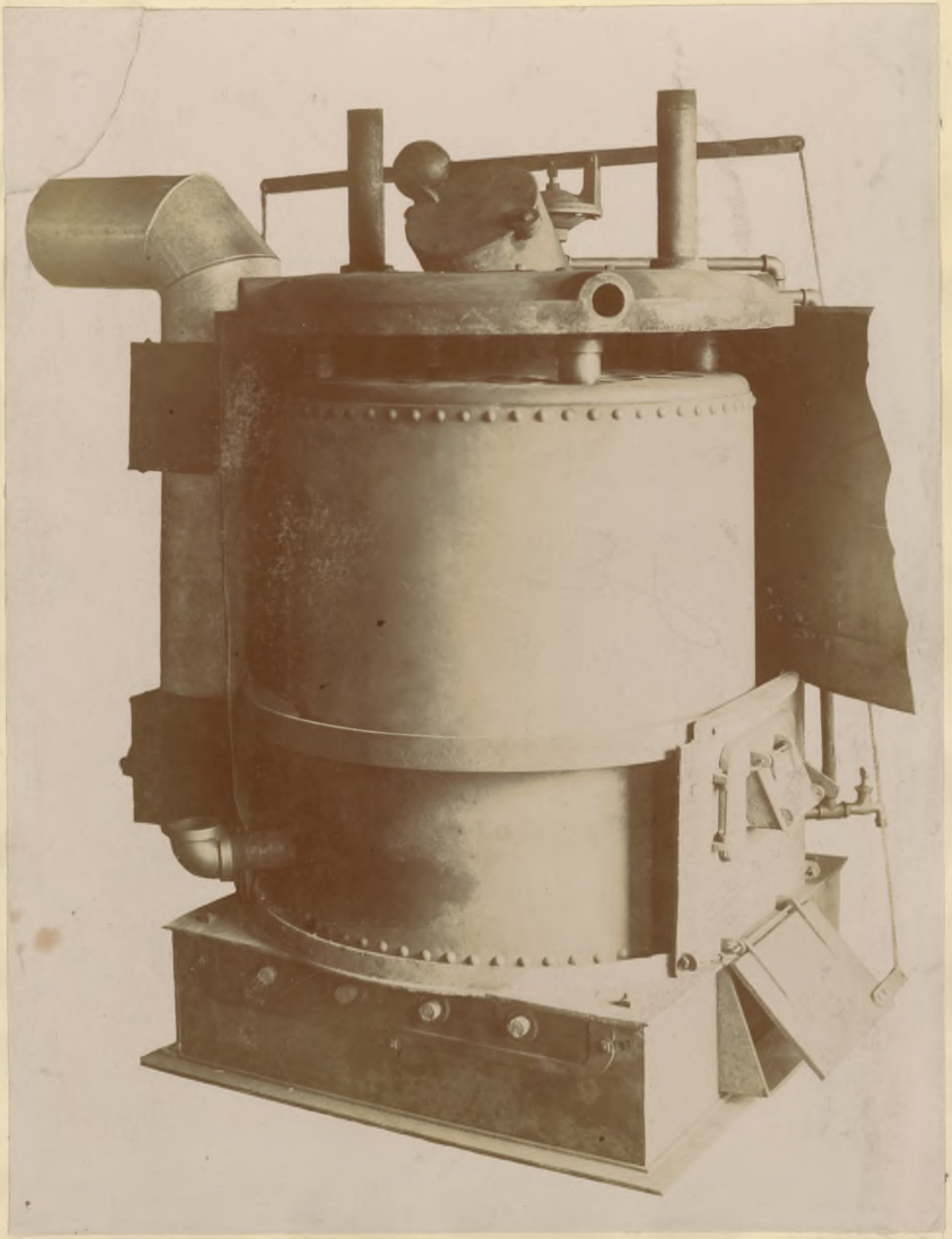
Average 58°.


Bath Room.
Average 70°.
85°
80°
75°
70°
65°
60°
55°
50°
Time 1 space = 2 hours.
Feb. 26
Feb.27
Feb.28
Mar.1
Mar.2
Mar.3
Mar.4


Kitchen Chamber.
Average 68°.
85°
80°
75°
70°
65°
60°
55°
50°
Time 1 space = 2 hours.
Feb.26
Feb.27
Feb.28
Mar.1
Mar.2
Mar.3
Mar.4



"ROBINSON + BURR'S" HEATER.



"ROBINSON + BURR'S" HEATER.

Mr. Page's House.

The residence of Mr. Page is a medium sized modern building. It faces the south and is practically unprotected, having no large trees or buildings very near. This house is without doubt, the coldest of the three. A part of the north side being even without lining of any sort. This fact may account, in a measure, for the low standing in the test.

The heater used is a rather ingenious affair of Mr. Page's design. Photographs are shown on one of the following pages.

A better grade coal than that of Professor Burrill's was burned. But the firing of the boiler was in a manner considered altogether wrong by all our text books. Instead of carefully spreading the coal on the grate, lumps were piled in front of the door, often leaving sections of the grate, near the bridge wall, entirely bare.

The amount of radiation in the building seems to have been insufficient.

Radiation according to Carpenter = 257 sq. ft.

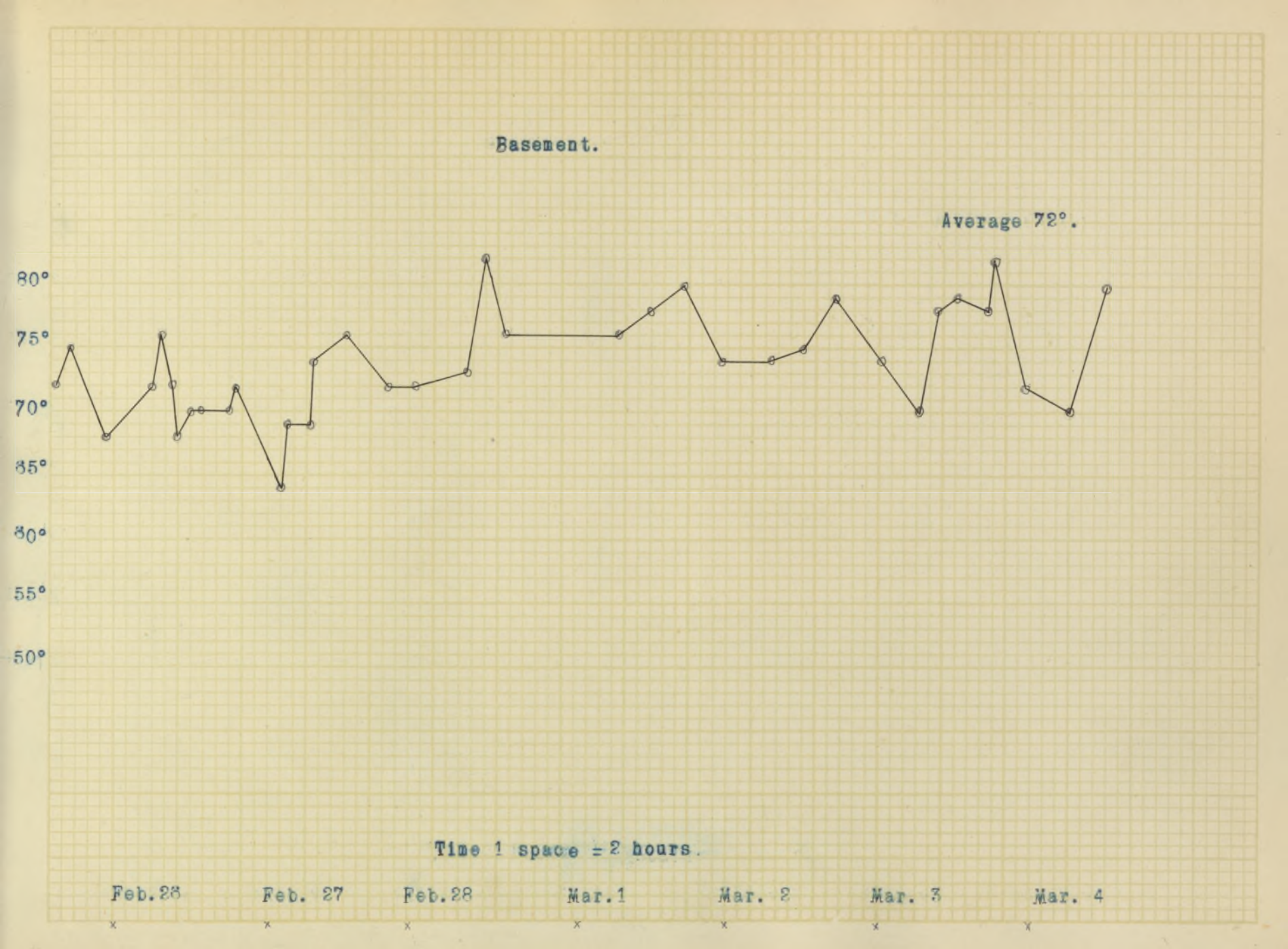
Radiation according to Mills = 282 sq. ft.

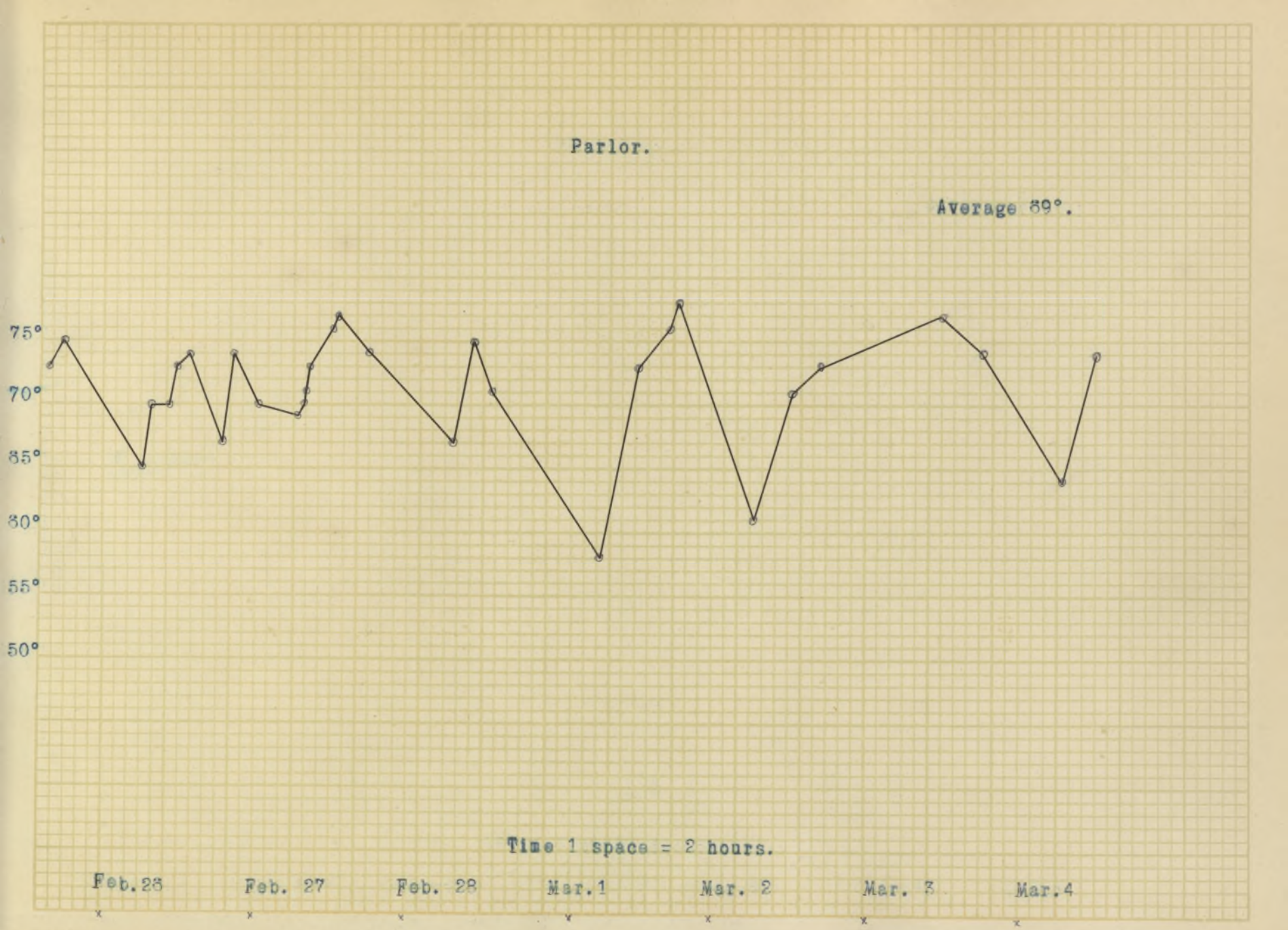
Radiation actual = 235 sq. ft.

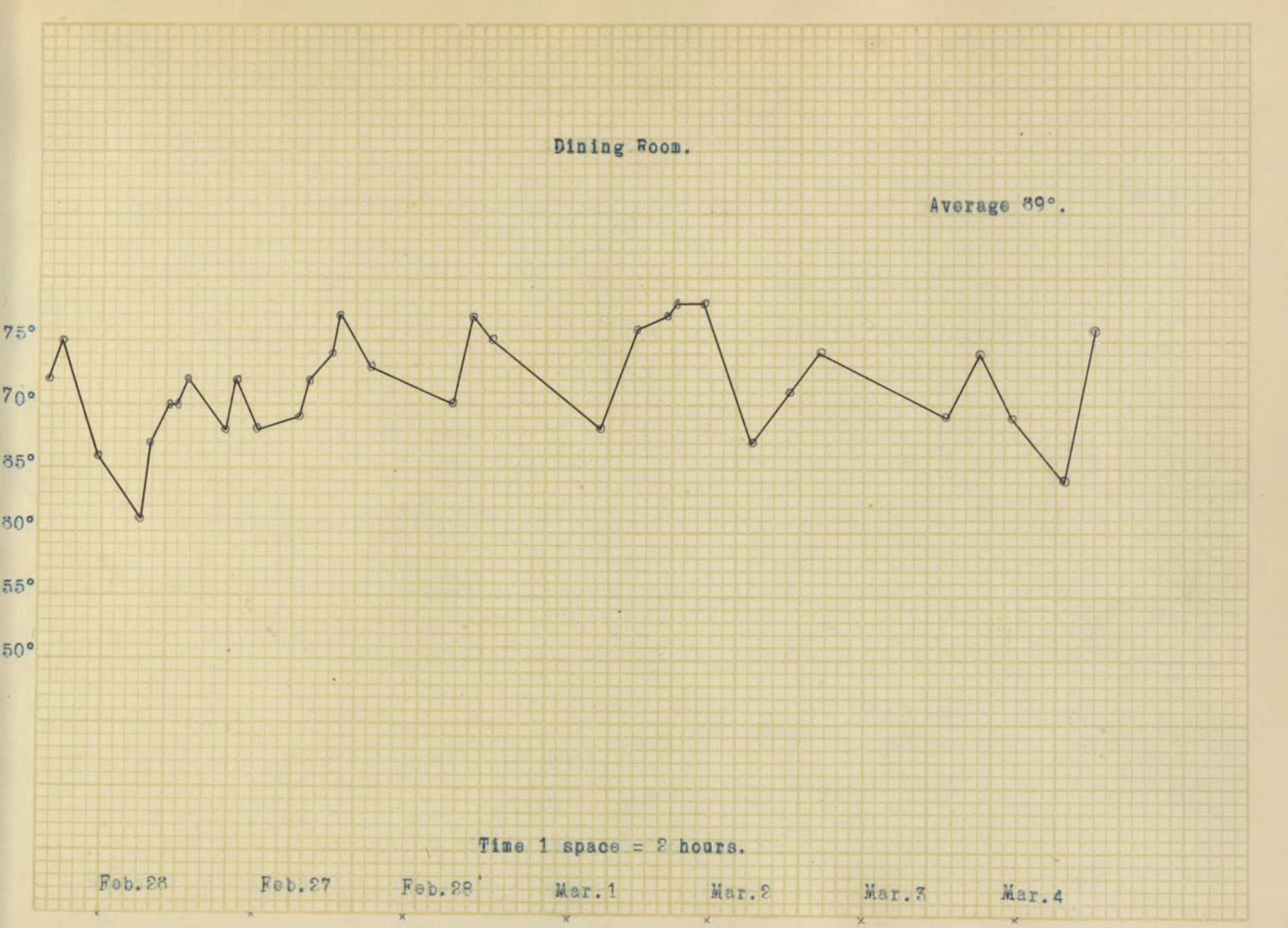
Insufficiency of radiating surface may, the writer thinks, have had some bearing upon the results of the test.

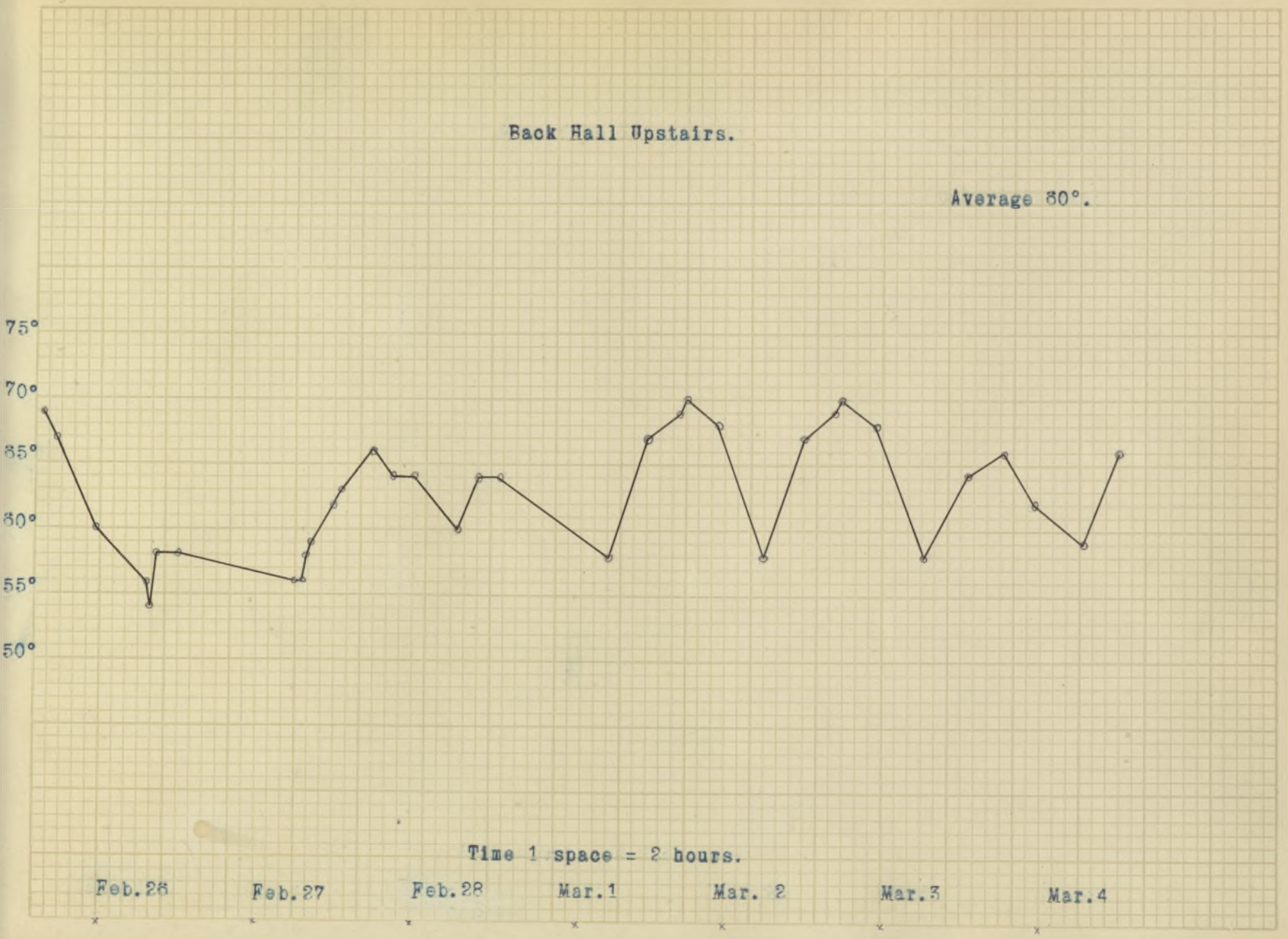
Mr. Page's House.

First Floor.	Sq.Ft. and Aspect of Glass Facing its each Apartment. N	E	W	S	Total No. of Sq.Ft. Glass.	Linear Ft. Exposed Wall and its Facing N	E	W	S	Total No. of Lin.Ft. of Exposed Wall	Sq.Ft. Exposed Wall.	Sq.Ft. Exposed Glass Area	Sq.Ft. Floor in each Apartment.	Cubic Contents.	Sq.Ft. Radiating Surface.(Carpenter).	Sq.Ft. Radiating Surface.(Mills)	Amount Used.
No.1. Parlor		11		19	30		14	3	12	29	281	231	188	1512	38	38	30
No.2. Hall								12	9	21	189	189	104	936	18	13	13
No.3. Sitting Room		11		10	21	3	14		4	24	212	190	175	1575	28	29	30
No.4. Dining Room	5		21	5	31		2	12	2	18	149	117	182	1728	25	31	34
No.5. Kitchen	21		5		26	18	11	11		38	338	311	140	1260	33	38	21
Second Floor.																	
No.6. Chamber		10		10	20		13		12	25	213	193	158	1328	24	28	28
No.7. Alcove			10	10	20			9	8	17	145	125	88	581	17	20	13
No.8. Chamber		10		10	20	5	13		4	22	187	187	158	1328	20	28	28
No.9. Chamber	10		10		20	11		18	2	29	247	227	148	1258	28	29	30
No.10. Bath	8				8	10	4		8	22	183	175	84.5	548	18	18	12
No.11. Hall		10	10		20			3	3	12	100	80	1385	1177	15	18	


Basement.
Average 72°.
80°
75°
70°
65°
60°
55°
50°
Time 1 space = 2 hours.
Feb. 26
Feb. 27
Feb. 28
Mar. 1
Mar. 2
Mar. 3
Mar. 4


Parlor.
Average 69°.
75°
70°
65°
60°
55°
50°
Time 1 space = 2 hours.
Feb. 26
Feb. 27
Feb. 28
Mar. 1
Mar. 2
Mar. 3
Mar. 4


Dining Room.
Average 69°.
75°
70°
65°
60°
55°
50°
Time 1 space = 2 hours.
Feb.26
Feb.27
Feb.28
Mar.1
Mar.2
Mar.3
Mar.4


Back Hall Upstairs.
Average 60°.
75°
70°
65°
60°
55°
50°
Time 1 space = 2 hours.
Feb.26
Feb.27
Feb.28
Mar.1
Mar. 2
Mar.3
Mar.4

West Chamber.

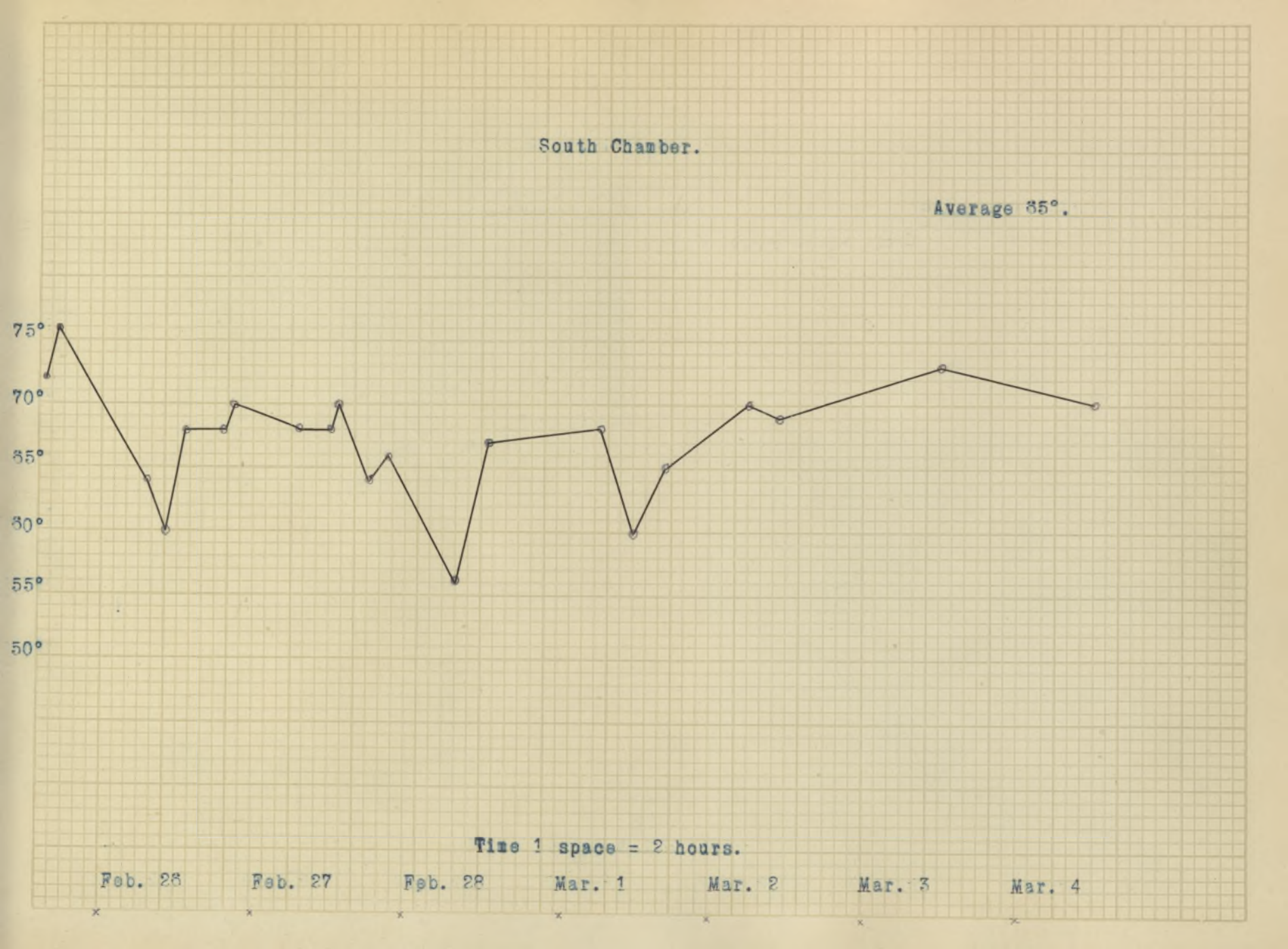
Average 84°.

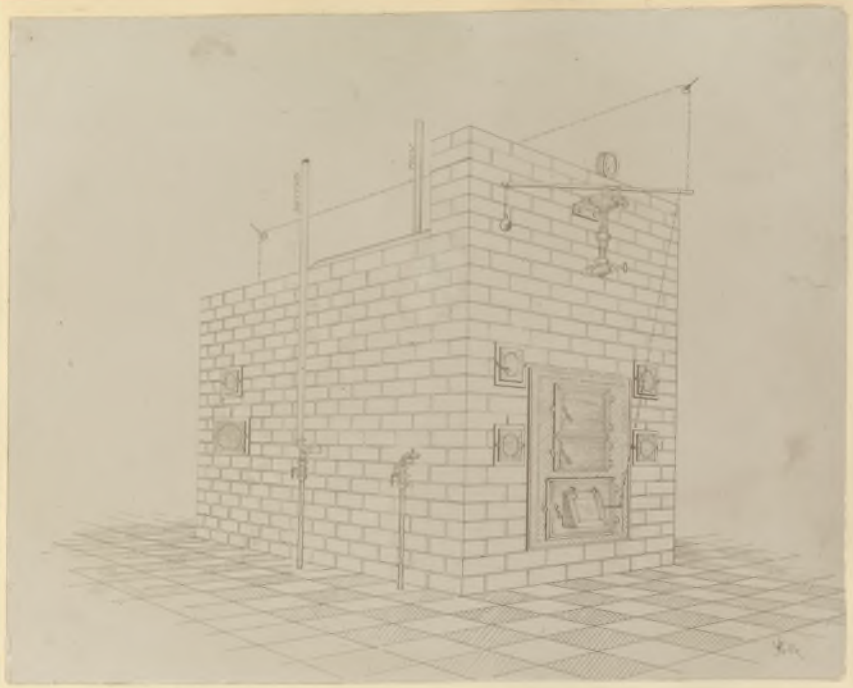
Time 1 space = 2 hours.

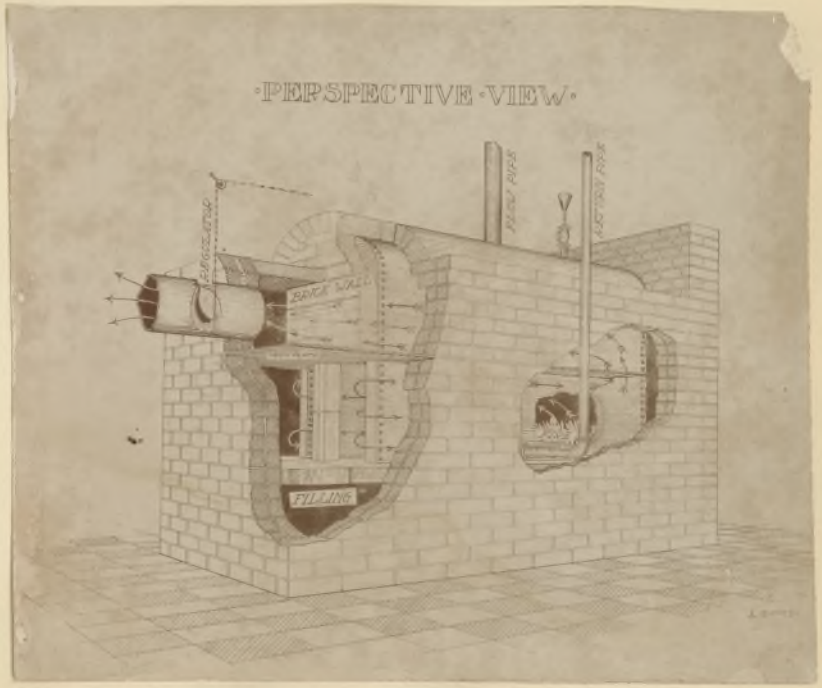
Feb.26 Feb.27 Feb.28 Mar.1 Mar. 2 Mar. 3 Mar. 4

South Chamber.

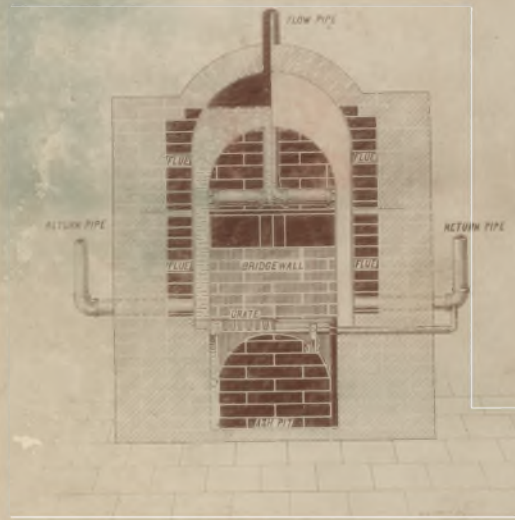
Average 65°.





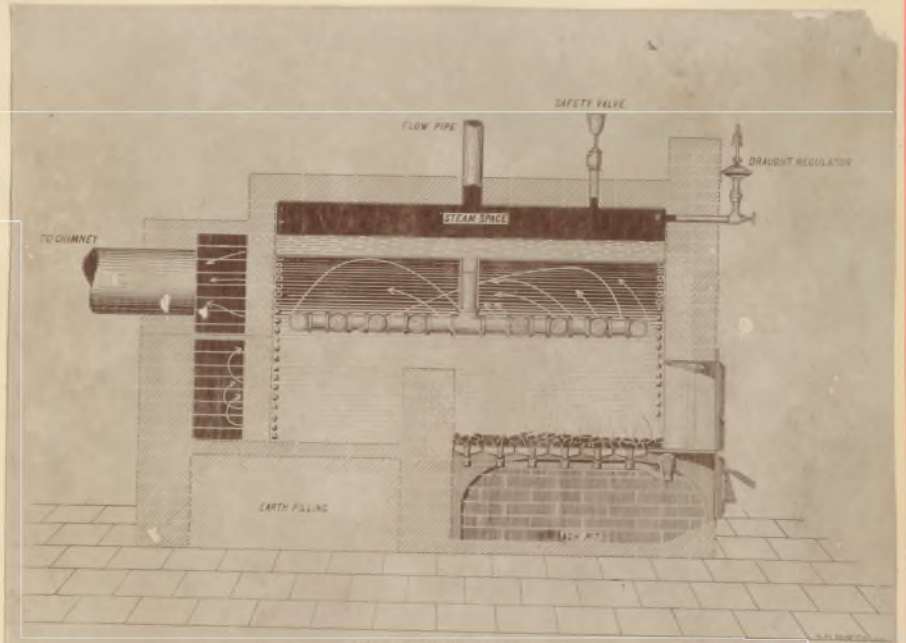


MR. PAGE'S HEATER



FRONT SECTIONAL VIEW.

MR. PAGE'S HEATER.



SIDE SECTIONAL VIEW.

Professor Breckenridge's House.

Professor Breckenridge's home is a two story frame building, fronting north. It seems to be a well constructed warm building.

The heater used is a "Cottage" Hot Water Heater manufactured by The H.B.Smith Co. of Westfield, Massachusetts. It is made of cast iron, and is in three sections. The entire apparatus in surrounded by water above the grate line. The furnace is of rectangular shape the base of which is the grate. In the rear corners we have two flues which lead up several inches and then come straight forward to a narrow chamber in the front of the heater. A single large flue there runs to the rear, through the centre of the heater, to the chimney. These flues which are elliptical in shape are entirely surrounded by water, a narrow sheet of water separating the lower line of flues from the top of the furnace.

Hard coal was used in firing the heater and a good, even fire was carried at all times. Since hard coal is so expenxive in this state, it is perhaps due to this cause that we have the cost of heating this house the amount that it is. Perhaps with a little more trouble to

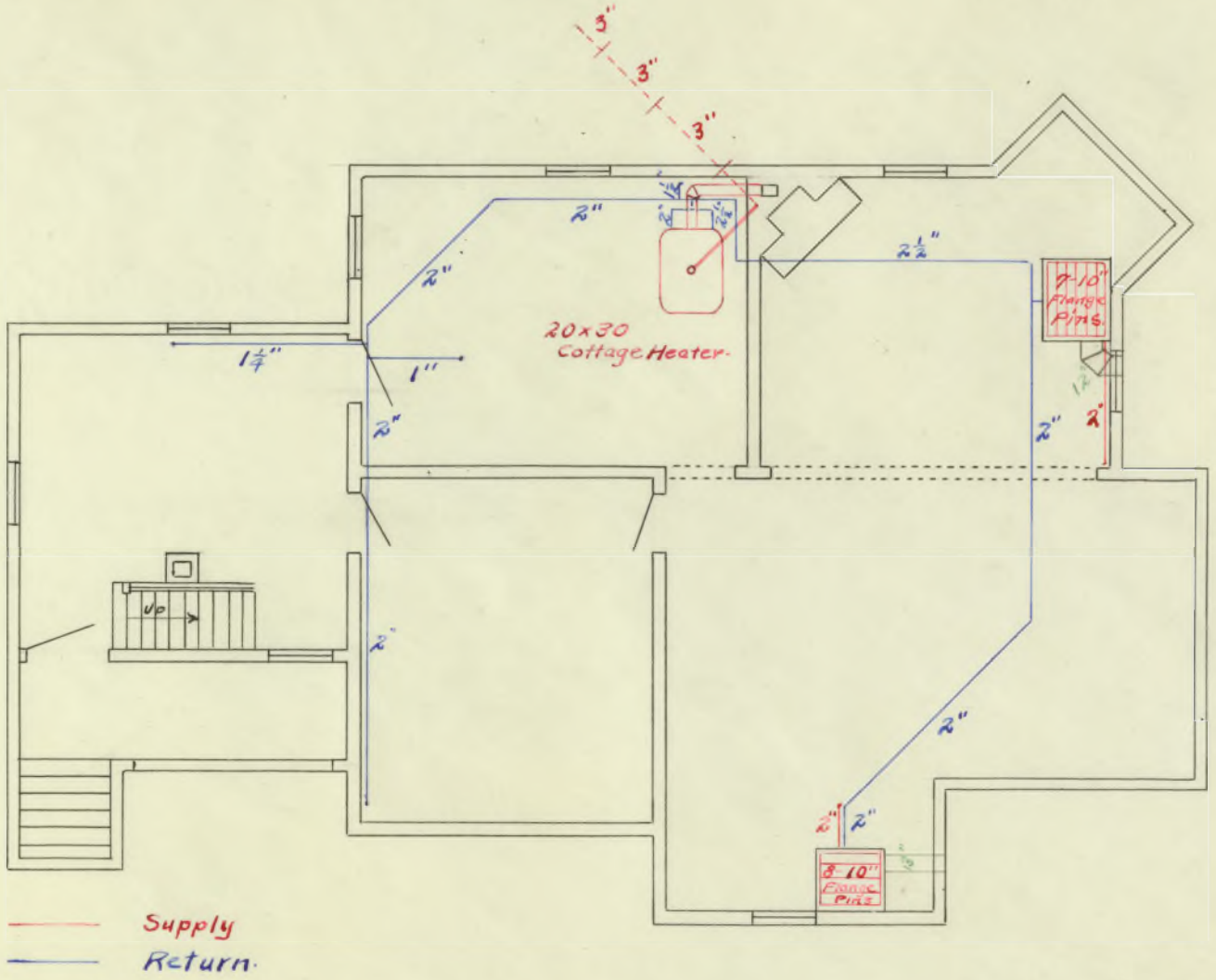
himself in the way of firing and ashes Professor Breckenridge could have warmed his house considerably cheaper had a good grade of soft coal been used.

One thing entering into Professor Breckenridge's test of which no account has been taken is the fact that he is ventilating his house. There is one indirect radiator in the hall which was, throughout the week, taking in the cold external air through a passage of 10 by 12 inches at a velocity of about 8 feet per second and discharging it, after supplying it with heat, into the house. Another indirect heater in the sitting room took air through an 8 x 12 space. Air at about 81° was passing up the fire place and out the chimney at all times.

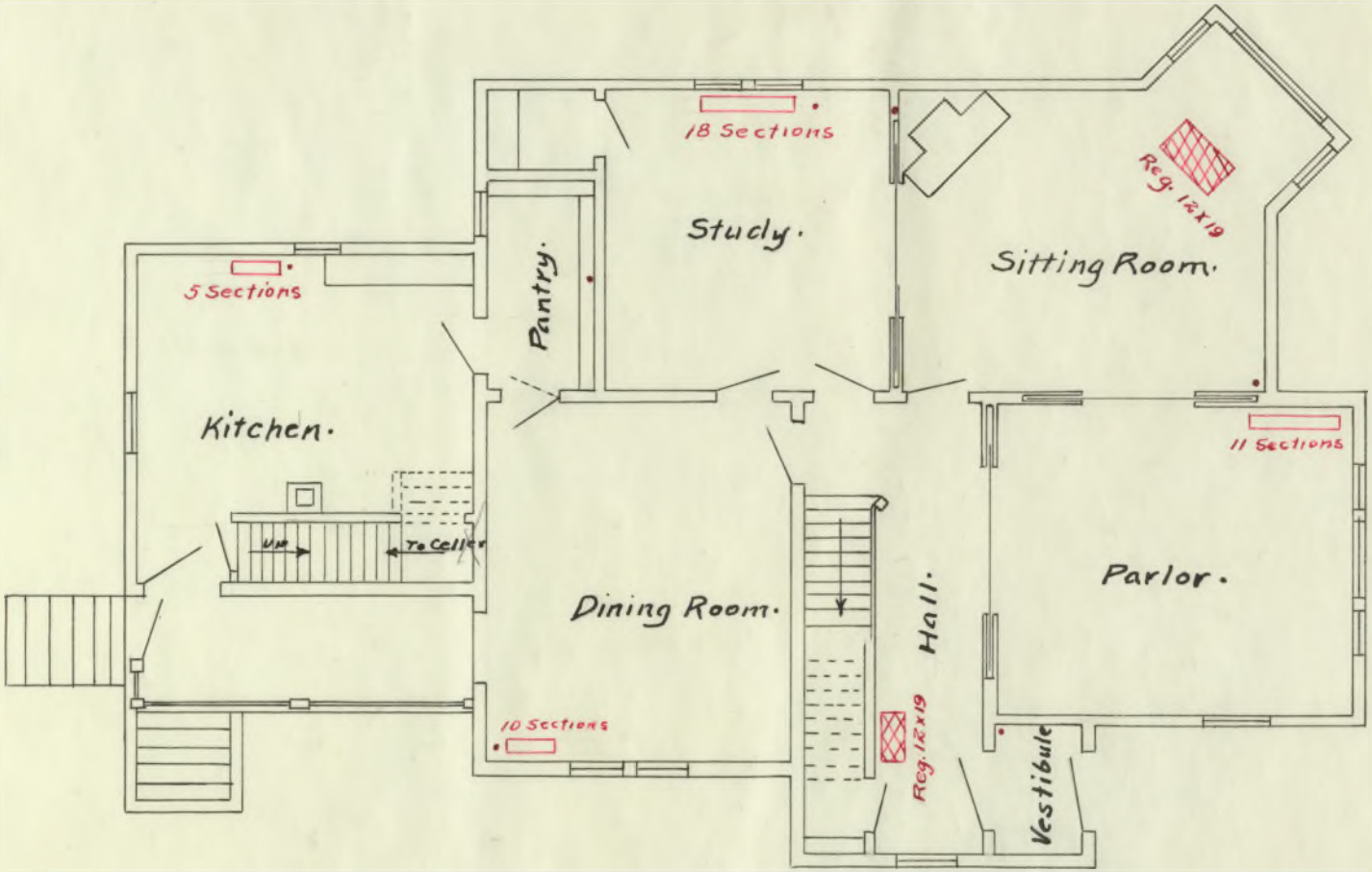
We can readily see that this meant a small cost at least. Considering an area of 1.5 sq. ft. as the combined area of the two ducts, with a velocity of 8 ft. per sec. we have 9 cubic feet as the discharge per second. Or that our heater must supply enough heat every minute to raise the temperature of 540 cubic feet of air from 28° F., the average external temperature, to 84° the temperature of the house.

Yet there seems to be no way of crediting the heater with this work, considering the

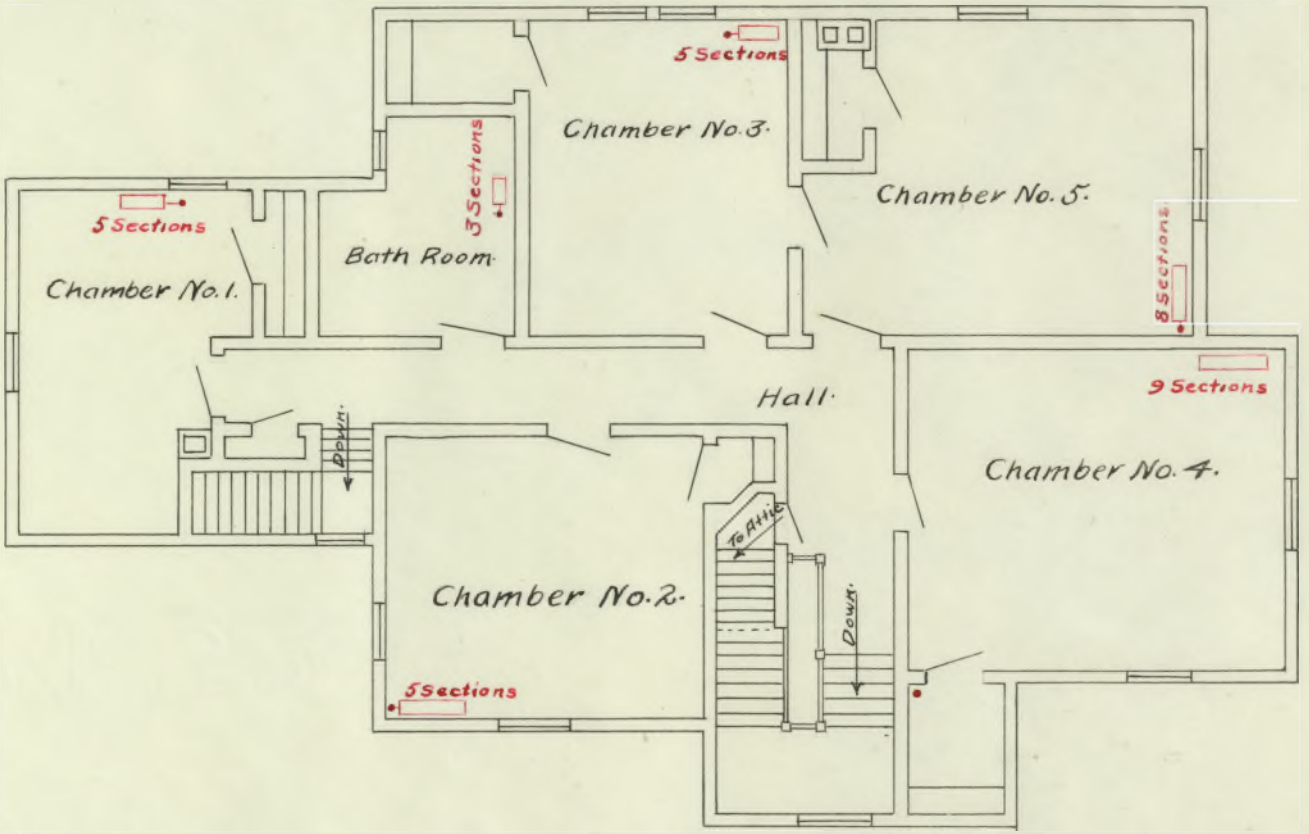
manner of conducting the test. It would have been quite possible, though, to have done so had the experimenter cumbered himself with the work of obtaining more extensive data; such as a large number of readings of the velocity of air through the ducts, analysis of coal and the like.


5"
3"
3"
2"
2"
2"
2½"
1¼"
1"
20x30
Cottage Heater.
7-10"
Flange
Pipes.
2"
2"
2"
2"
2"
2"
2"
Up
8-10"
Flange
Pipes
Supply
Return.

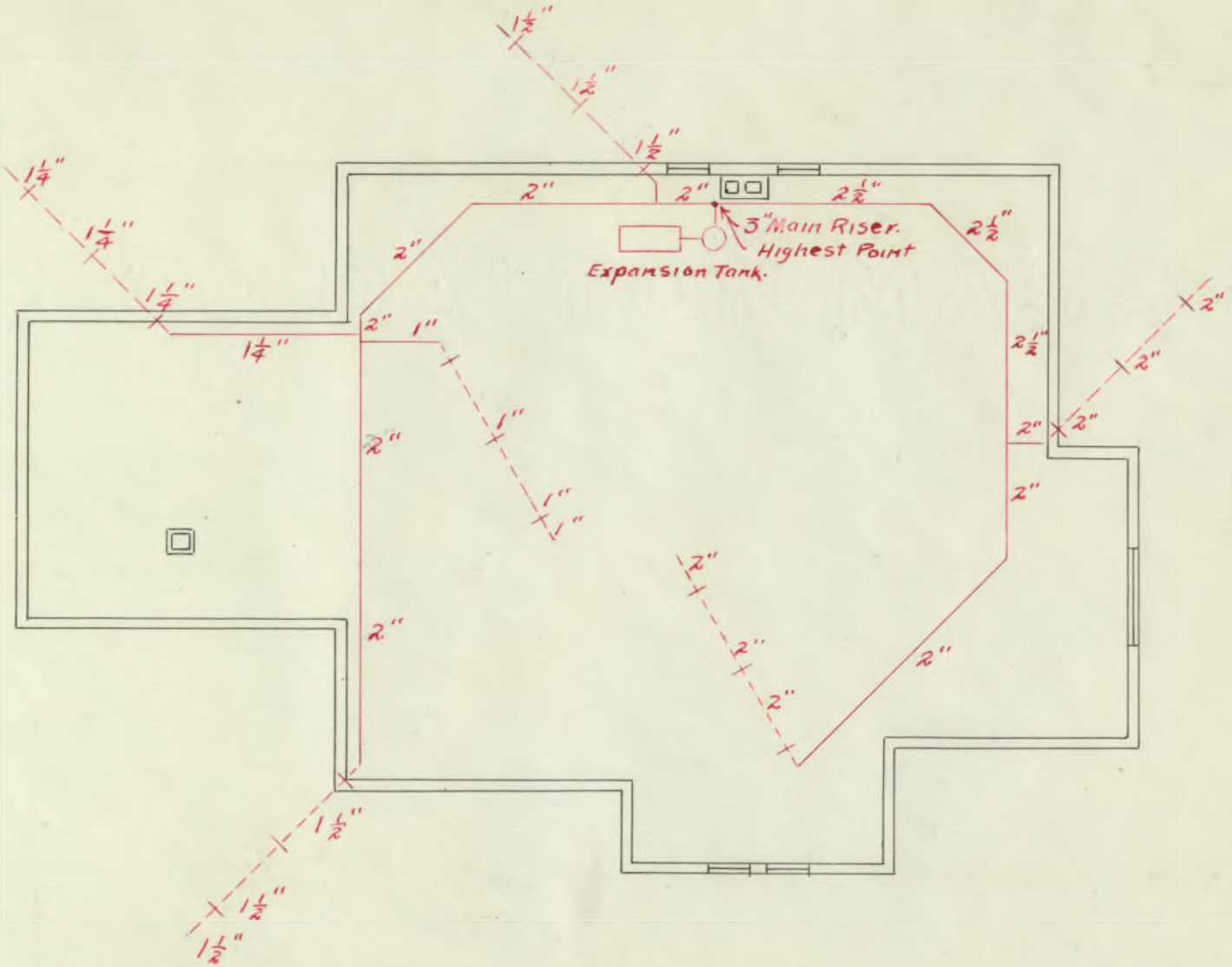
BASEMENT.


18 Sections
Reg. 12x19
Study.
Sitting Room.
5 Sections
Pantry.
Kitchen.
11 Sections
Up
To Cellar
Dining Room.
Hall.
Parlor.
10 Sections
Reg. 12x19
Vestibule

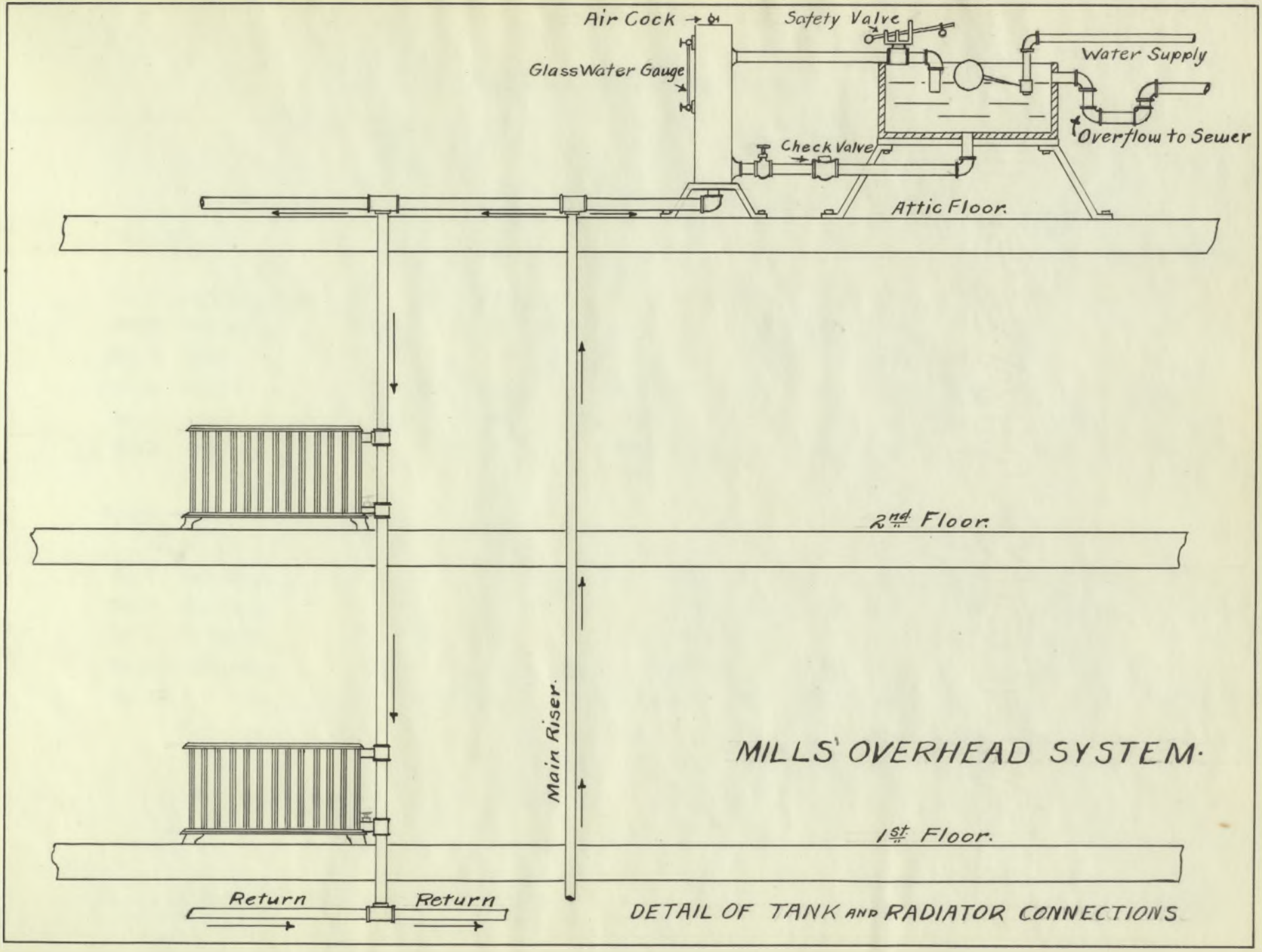
FIRST FLOOR.



SECOND FLOOR.


1½"
1½"
1½"
1¼"
1¼"
1¼"
2"
2"
2½"
3" Main Riser.
Highest Point
Expansion Tank.
2½"
2"
2"
2"
1"
1"
1"
2"
2"
2"
2"
2"
2"
2"
2"
2"
2"
1½"
1½"
1½"

ATTIC.

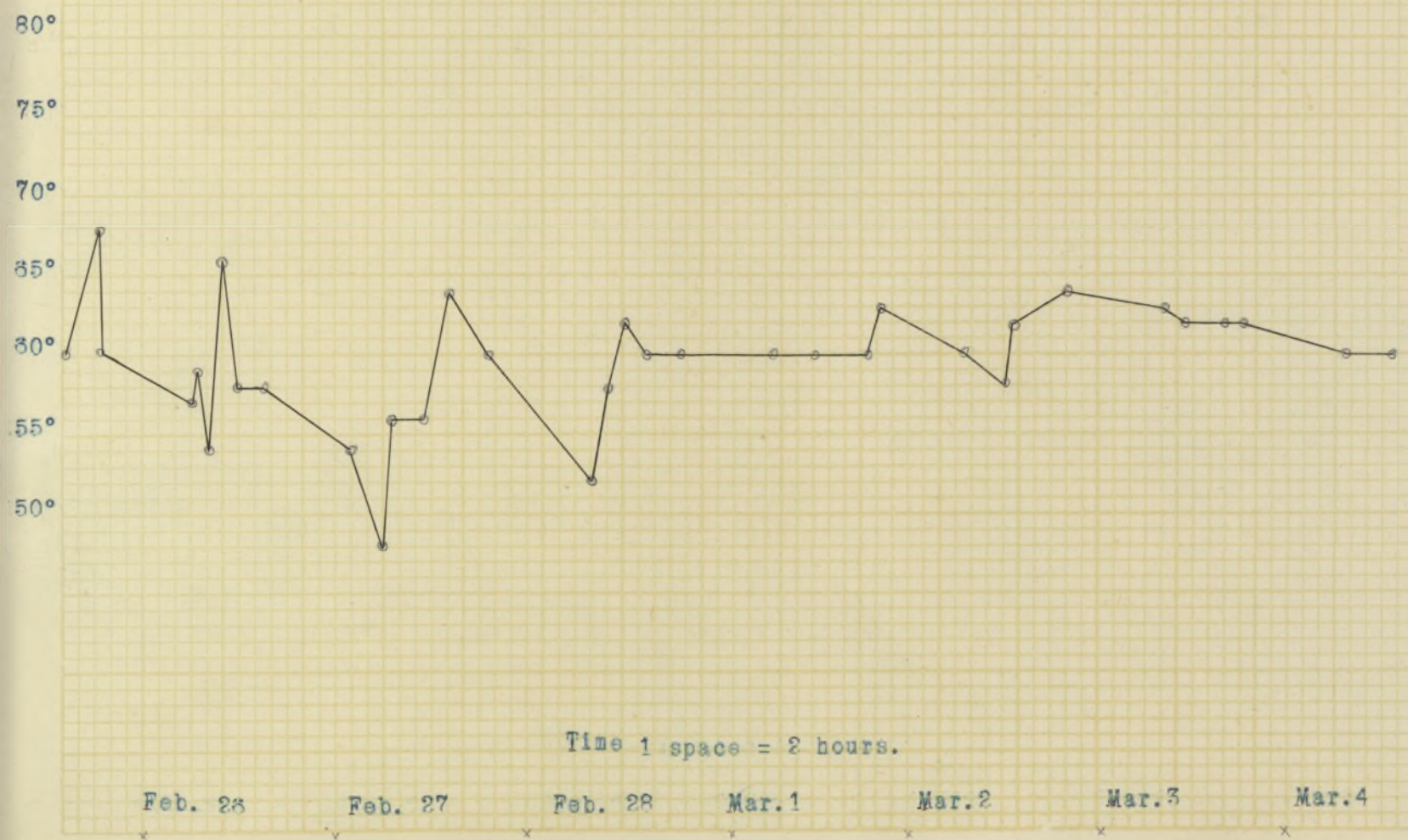

Air Cock
Safety Valve
Water Supply
Glass Water Gauge
Overflow to Sewer
Check Valve
Attic Floor.
2nd Floor.
Main Riser.
1st Floor.
Return
Return
MILLS' OVERHEAD SYSTEM.
DETAIL OF TANK AND RADIATOR CONNECTIONS

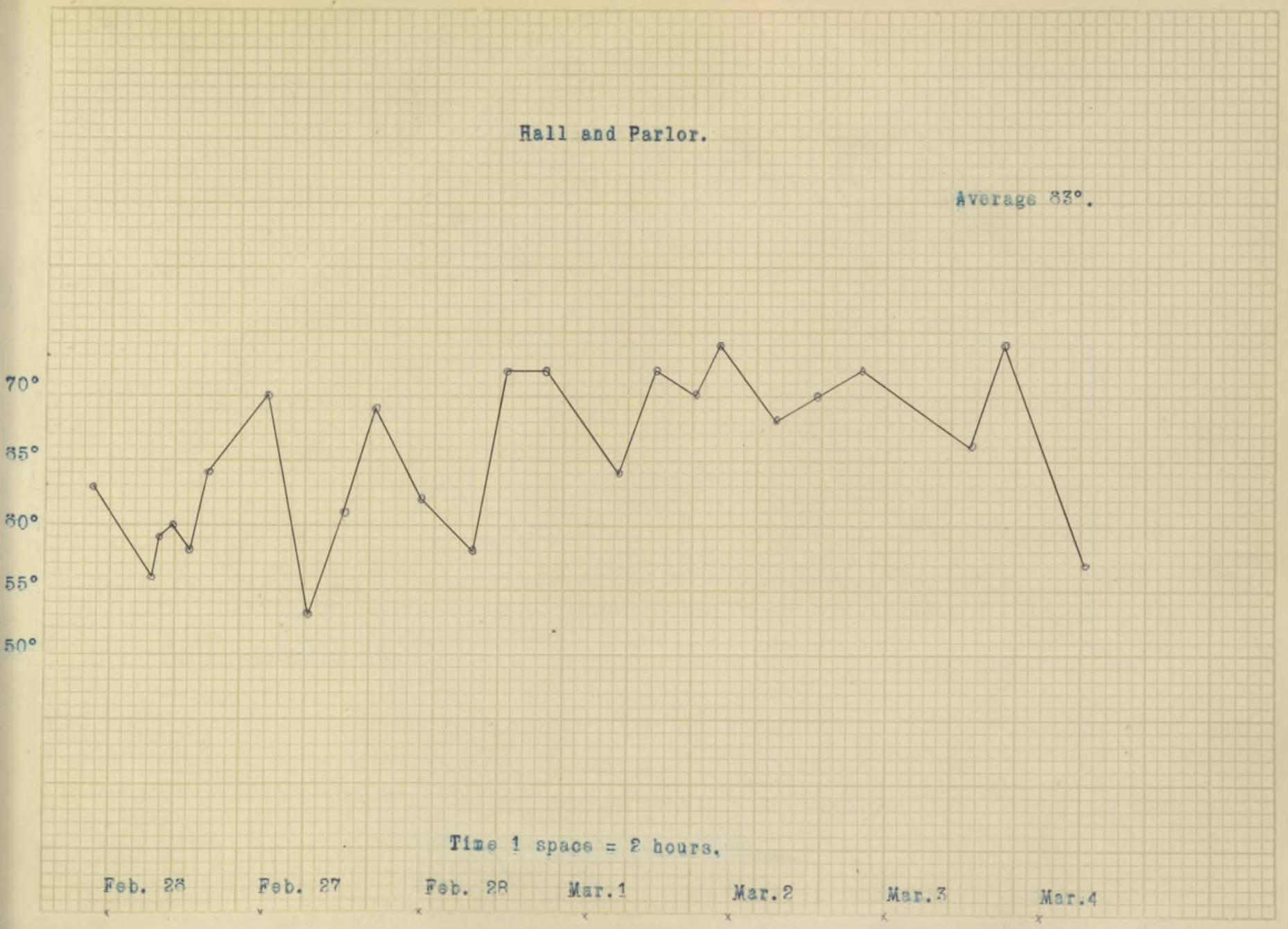
Professor Breckenridge's House.

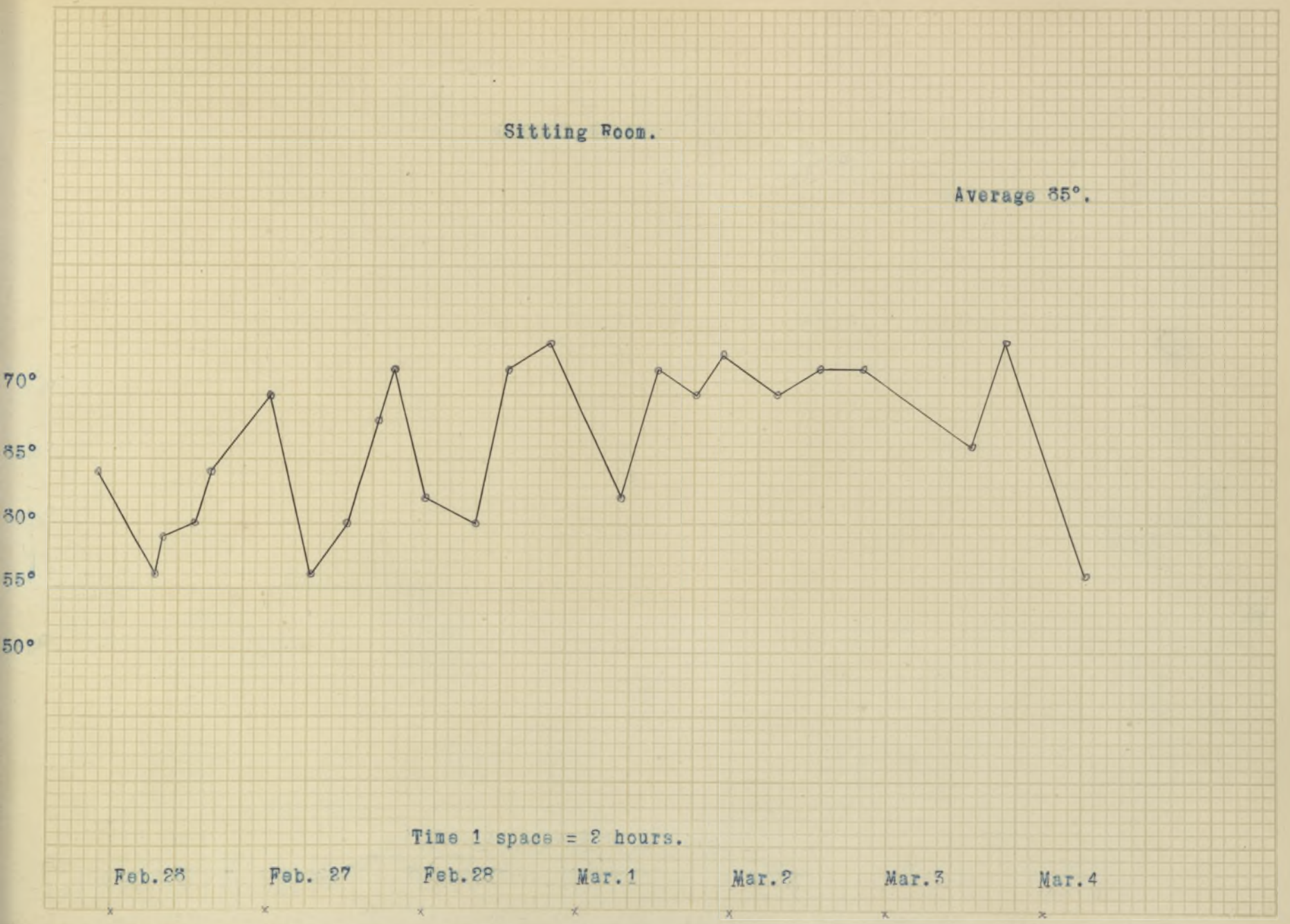
First Floor.	Sq.Ft. and its facing in each Apartment. N	E	W	S	Total No. Sq. Ft. Glass.	Linear Ft. of Exposed wall. N	E	W	S	Total Linear Feet.	Total No. Sq. Ft. Exposed wall.	Sq. Ft. exposed wall less glass.	Sq. Ft. Floor in each apartment.	Cubic Contents.	Sq. Ft. Radiating Surface. (Carpenter).	Sq. ft. radiating surface. (Mills)	Surfaces corresponding to theoretic.	Actual radiation Sq. Ft.
No.1. Sitting Room	33		12		45	18.5		19		35.5	355	310	232	2320	86.5	80	84	
No.2. Parlor	38	18			52	14.5	12	4		30.5	305	253	218	2180	83.2	79	81	715
No.3. Hall		15			15		8.5		4	12.5	125	110	188	1880	45.8	38	42	
No.4. Study			28		28			18	4	22	220	194	178	1780	57	84	81	45
No.5. Dining Room		28			28		13.5		7.5	21	210	184	208	2080	81.8	57	80	85
No.6. Kitchen			14	19	33			18	18.5	34.5	345	312	289	2890	88.8	72	79	325
Second Floor.																		
4 No.7. Bed-room	14	14			28	21	13.5	4		41.5	387	357	247	2305	88.8	83	85	585
5 No.8. Bed-room	14		14		28	14		17		31	289	281	229	2137	55.8	55	55	52
No.9. Bed-room			23		23		18		4.5	22.5	210	187	179	1870	42	42	42	325
No.10. Bed-room		14		11	25		13.5		8	21.5	201	178	188	1588	41.2	42	42	325
No.11. Bed-room			11	11	22		7.5	13.5	15	38	338	314	128	1195	51.2	47	49	325
Bath-room				5	5			3.5	3.5	8	58	51	80	580	11.8	11.3	115	195
Front Hall		14			14		8.5		4	12.5	117	103	213	1988	31.8	32	32	
Back Hall		7			7		9			9	84	77	88	835	18	15	155	
Indirect Radiation in Sitting Room																	130	105
" " " Hall # 3																	70	120

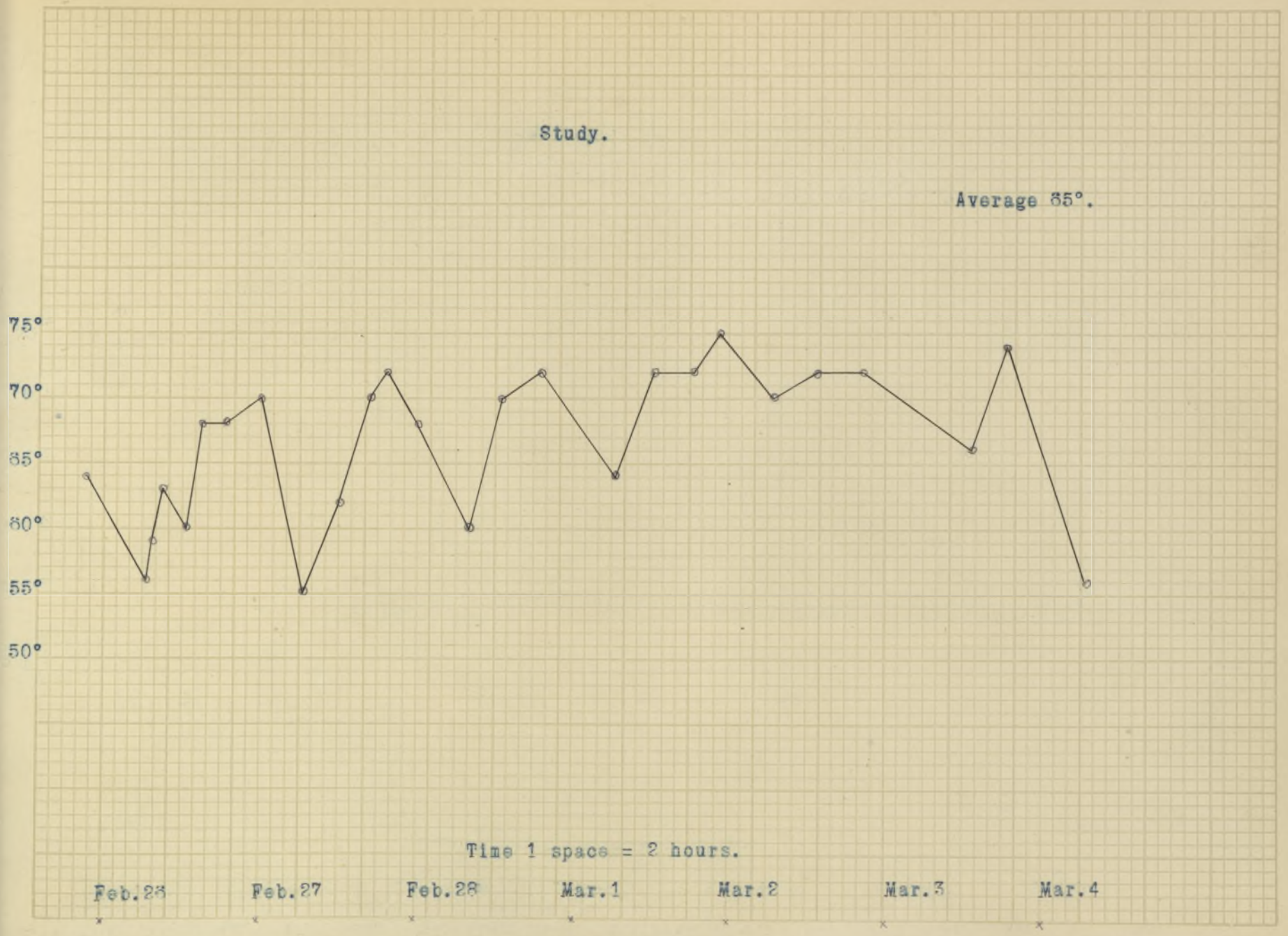
Basement.

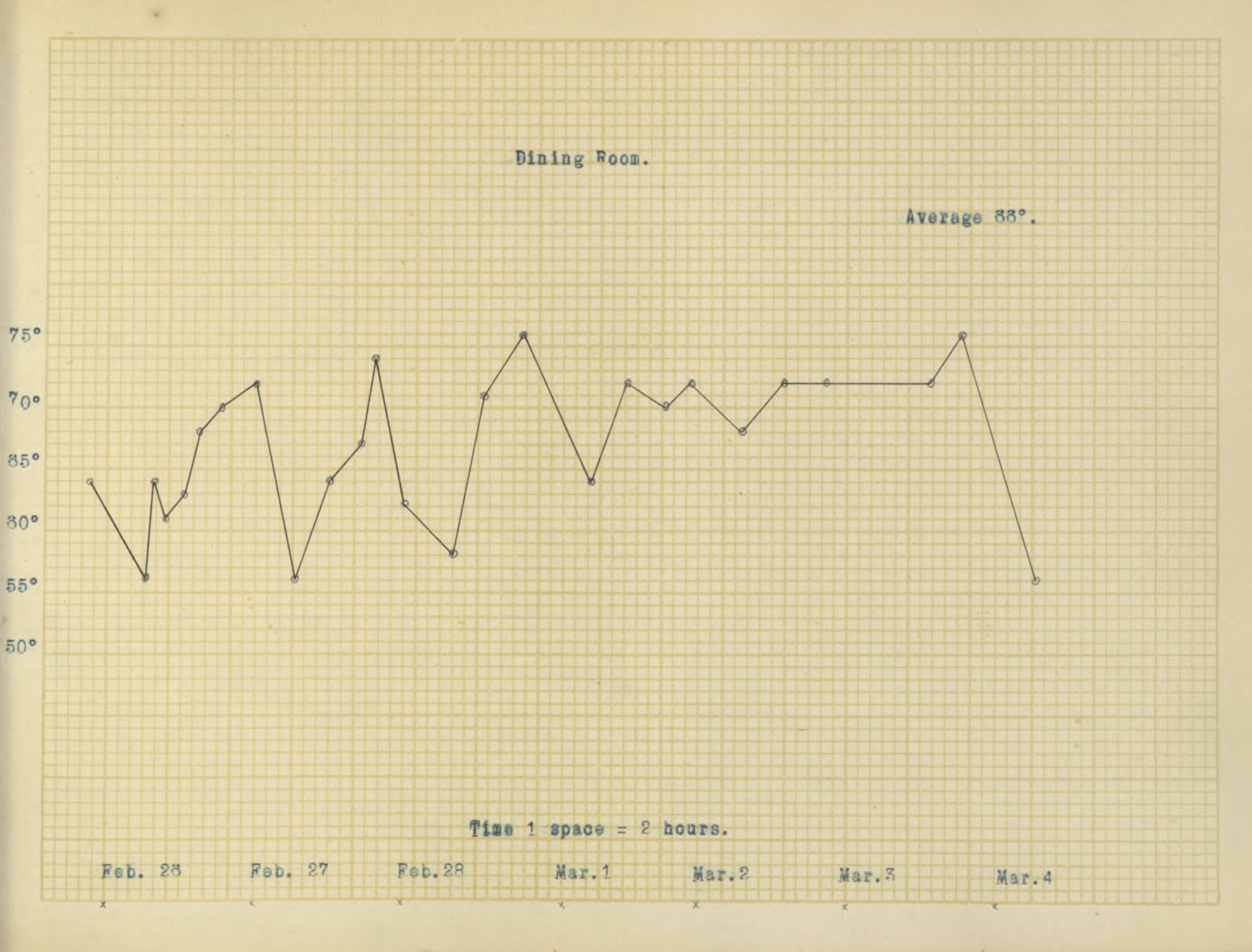
Average 57°.




Hall and Parlor.
Average 63°.
70°
65°
60°
55°
50°
Time 1 space = 2 hours.
Feb. 26
Feb. 27
Feb. 28
Mar. 1
Mar. 2
Mar. 3
Mar. 4

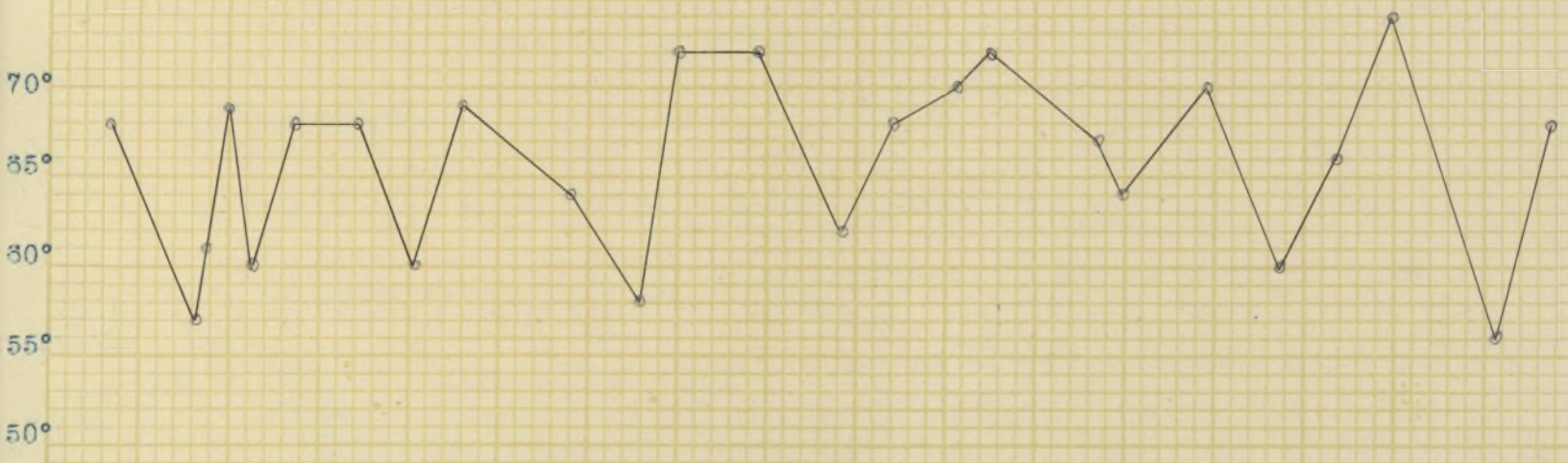

Sitting Room.
Average 65°.
70°
65°
60°
55°
50°
Time 1 space = 2 hours.
Feb.26
Feb. 27
Feb.28
Mar.1
Mar.2
Mar.3
Mar.4


Study.
Average 65°.
75°
70°
65°
60°
55°
50°
Time 1 space = 2 hours.
Feb.26
Feb.27
Feb.28
Mar.1
Mar.2
Mar.3
Mar.4


Dining Room.
Average 68°.
75°
70°
65°
60°
55°
50°
Time 1 space = 2 hours.
Feb. 26
Feb. 27
Feb. 28
Mar. 1
Mar. 2
Mar. 3
Mar. 4

Average Upstairs.

Average 64°.



Time 1 space = 2 hours.

Feb. 26 | Feb. 27 | Feb. 28 | Mar. 1 | Mar. 2 | Mar. 3 | Mar. 4

Steam vs. Hot Water.

The number of comparative tests of steam and hot water heating apparatus are few. All the records that the writer was able to find showed that water was the more economical. Yet steam and water in a radiator have practically the same efficiencies in warming air. Owing to the great specific heat of water and its density, the amount of heat contained in a radiator is much greater for water than for steam; but the latter flows more rapidly, and its condensation upon the surface of the metal liberates latent heat, which becomes sensible in the iron, and maintains it at nearly the same constant temperature.

The economy lies, perhaps, principally in the fact that in the mild weather, of which we have considerable of in this country, a sufficient amount of heat would have to be supplied to "get up steam" in a steam heater while in the use of hot water the temperature would have to become, say, only 140° or 150°.

Mills in his second volume on heating and ventilation sums the entire subject up in such a complete manner that he leaves no ground uncovered from the installation of plant to its com-

plete working. A copy of this table is given on the following page.

Conditions and Results.

Steam.	Water.
Three elements involved: water, air, steam.	One element involved.
Boiler Pressure essential.	Boiler Pressure not essential.
Equal Pressure essential.	Equal Pressure not essential.
A water line essential.	A water line not essential.
Grade of pipes essential.	Grade of pipes not essential.
Fixed temperature essential.	Fixed temperature not essential.
Heat only with pressure.	Heat without pressure.
Any radiator available.	Special radiator required.
All heat below 212° lost.	All heat utilized.
Available heat limited.	Available heat unlimited.
Circulation not always silent.	Circulation silent and continuous.
Increased duty weakens circulation.	Increased duty increases circulation.
Economy - water 100%; steam 75 to 80%.	

Boiler Tests.

On the following pages are given the results of six tests on a "Cottage" Steam heater which was kindly lent to the department by the manufacturer H. B. Smith Co., of Westfield, Massachusetts. It was set up in the Mechanical Engineering laboratory, and a considerable number of tests made. For various reasons only six tests of any value were obtained.

Test Number	1	2	3	4	5	
14.Of steam, degrees, Fah.	226.08	219.82	226.82	223.08	223.2	226.9
Fuel.						
15.Moist coal consumed, lbs.	95	139	44	80	88	80
16.Moisture in coal, per cent.			2%			
17.Dry coal consumed, lbs.	93.1	136.2	43.1	59.9	84.3	78.4
18.Wood consumed, lbs.	3	4	4	5	5.5	3
19.Coal equivalent of wood(= item 24x.4), lbs.	2.4	1.6	1.6	2	2.2	2.4
20.Total dry coal consumed including wood equivalent, lbs	95.5	137.8	44.7	61.9	86.5	80.8
21.Total dry refuse, lbs.	22	25.5	18	17.4	25	28
22.Total dry refuse, per cent.	23%	18	41	29	29	35
23.Total combustible,(= item 28- item 27), lbs.	73.5	112.3	26.7	44.5	61.5	52.8
24.Dry coal consumed per hour, lbs.	11.8	34.4	10.8	14.9	10.5	9.8
25.Combustible consumed per hour, lbs.	9.1	28.75	6.7	11.1	7.7	6.6
Description of Fuel.						

University of Illinois,
Mechanical Engineering Laboratory.

1. Results of Boiler Trial at	Mechanical Engineering Laboratory.					
2. Kind of Boiler	"Cottage".					
3. Type of boiler	Steam House Heating.					
4. Test Number	1	2	3	4	5	6
5. Duration of trial	8	4	4	4	8	8
Governing Proportions.						
6. Grate surface, square feet	3.25					
7. Water heating surface, square feet	21.91					
8. Ratio water heating surface to grate surface, 1 to ?	6.4					
Aver. Press. and Tempt.						
9. Steam pressure in boiler, by gauge, lb per sq.in.	4.8	2.4	3.8	4.1	4.2	4.9
10. Of external air, degrees, Fah.	25	28	28	58	57	51
11. Of fire room, degrees, Fah.	85	89	85	74	74	78
12. Of feed water, degrees, Fah.	179	122	118	159	187	148
13. Of escaping gases, degrees, Fah.	149	530	142	153	147	140

Test Number.	1	2	3	4	5	6
26. Commercial name.	Odin.					
27. Commercial size.	Lump.					
28. Lumps, per cent.	90					
29. Small coal, per cent.	10					
30. Slack, per cent.	0					
31. Appearance of coal.	Dull.					
Quality of Steam.						
32. Quality of steam.	Variable.					
Water.						
33. Total water pumped into boiler, lbs.	517	789	201	253	491	481
34. Equivalent water from and @ 212° Fah., lbs.	538.7	838.2	221.1	288.2	518.5	515.2
35. Equivalent water from ℉ @ 212° F., per hr., lbs.	87.08	209.5	55.2	87.0	84.5	84.4
Evaporative Performance.						
36. Equivalent water from ℉ @ 212°F. per lb of dry coal lb	5.8	6.2	5.1	4.4	6.1	6.5

Test Number.	1	2	3	4	5	6
37. Equiv. water from # @ 212°F. per lb of combustible lb	7.3	7.5	8.2	8.0	8.3	9.7
Commercial Horse-Power.						
38. On basis of 34.5 lbs of water from # @ 212°F per hr, HP	1.8	8.7	1.8	1.9	1.8	1.8
39. No. of sq ft of heating surface per commercial H.P.	14.1	13.3	3.8	11.5	12.1	12.1
40. H.P. per sq. ft. of grate surface.	.48	2.0	.49	.58	.55	.55
Rate of Combustion.						
41. Dry coal burned per hr. per sq. ft. of grate surface, lbs	3.83	10.8	3.3	4.5	3.2	3.0
42. Dry coal burned per hr. per sq. ft. of water heating surface, lbs.	.54	1.8	.49	.57	.47	.44
Rate of Evaporation.						
43. Water evaporated per hr. from # @ 212°, F. per sq. ft. of grate surface, lbs.	20.9	84.4	18.9	20.8	19.8	9.9
44. Water evaporated per hr. from # @ 212°, F. per sq. ft. of heating surface, lbs.	3.08	9.5	2.5	3.0	2.9	2.9
Cost.						
45. Cost of coal per 2000 lbs. at boilers, dollars.						